HOW TO MAKE STRUCTURAL RETURN LOSS MEASUREMENTS

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1. GENERAL

1.1 This section is intended to provide REA borrowers, consulting engineers, contractors and other interested parties with technical information for use in the design and construction of REA borrowers' telephone systems. It provides in particular, technical information for use when making Single Frequency Structural Return Loss measurements (SFSRL) and Echo Structural Return Loss Measurements (ESRL) on D-66, H-88 and D-66/H-88 loaded cable plant intended for trunk or subscriber loop applications. This section describes how to make the structural return loss measurements.

1.11 This section provides specific information on the following:

1.111 The return loss theory underlying the measurements.

1.112 How to measure the structural return loss (SFSRL and ESRL) of uniform D-66 or H-88 loaded single gauge cables.

1.113 How to measure the structural return loss (SFSRL and ESRL) of D-66 or H-88 mixed gauge cables.

1.114 How to measure the structural return loss of D-66/H-88 loaded cables using the D-66/H-88 junction impedance compensator.

1.115 Required test equipment for conducting the measurements.

1.116 Component and wiring information for constructing test hybrids and D-66 and H-88 precision networks when the need arises.

1.117 Illustrative results of cables measured in REA borrowers' systems.

1.118 Data sheets for recording measurement data.

1.2 The measurements described herein are not applicable to loaded trunk cables which contain lengths of rural distribution wire, non-loaded cable, open wire conductors or trunk plant which consists entirely or predominantly of rural distribution wires. Issue No. 2 of this section replaces Section 445, Issue No. 1, in its entirety.

1.3 The actual step-by-step measurement procedures for SFSRL and ESRL are discussed in paragraph 8.

2. THE MID-SECTION IMPEDANCE OF A LOADED CABLE

2.1 For every telephone line with uniformly distributed constants, there is a value of impedance such that if the line is terminated in this impedance no reflections exist at that end. This impedance is known as the characteristic impedance of the line. The characteristic impedance can also be defined as the input impedance of an infinitely long line without regard to the value of the terminating impedance at the receiving end.

2.11 Regardless, however, of the definition used the important consideration is that <u>if a line is terminated in its characteristic impedance the reflected energy is zero at every point in the line.</u>

2.2 In a loaded cable the amount of inductance added by the loading coil is large as compared to the inductance of the cable pair (about 80 times to one for D-66 and H-88 loading). Since the impedance of any line increases as the inductance of such a line increases, this tends to raise the characteristic impedance of the line. Therefore, the value of the characteristic impedance of a loaded cable pair is generally higher than that of a non-loaded cable pair of the same gauge at the same frequency, except at very low frequencies where the loading is not effective and the two impedances are nearly equal.

2.3 A loaded cable differs significantly from a non-loaded cable in this respect. The inductance of the non-loaded cable pair is uniformly distributed (the same value of inductance for each small increment in cable length) whereas the loaded cable has its inductance lumped at discrete intervals (at intervals of 4500 feet, for example, for D-loading). Loading a cable produces two important characteristi

2.31 The loaded cable now acts as a low pass filter with a cutoff frequency determined by:

$$f_c = \frac{1}{\pi \sqrt{LC}}$$

where L is the sum of the loading coil and cable pair inductance per full loading section length henries, C is the cable pair mutual capacitance per full loading section length in farads and f_c the toff frequency in cps.

32 The value of the characteristic impedance of the loaded cable depends upon <u>the point in the end-section at which it is measured. That is, the value of this impedance is different at different ints along the end-section.</u> The length of the end-section at the point of measurement is usually pressed as a percentage of the full load spacing for the particular loading system in question. For

example, if impedance measurements are made between the 2250 foot ends of a D-66 loaded system, these measurements would represent the impedance of the cable between 0.5 end-sections (ES) or better known as Mid-Section Impedance. For an H-88 loading system, the mid-section impedance would require only 3000 feet of end-section length.

2.321 Fig. 1 shows the variation in the magnitude of the mid-section impedance of a 22-gauge exchange type cable D-66 and H-88 loaded in the frequency range of 200 to 4700 cps, including the region of the cutoff frequency. From inspection of the H-88 curve, it will be seen that the characteristic impedance remains relatively flat at approximately 1000 ohms in a very narrow frequency range of 700 to 1300 cps. At other frequencies large impedance changes occur with changes in frequency. The D-66 impedance curve displays less variation in the same frequency range. At 3000 cps, for example, its mid-section impedance rises only to 1270 ohms. To illustrate the effect which the length of the end-section has on loaded line impedance, Fig. 2 shows such a typical variation for a 24 and 22 gauge exchange type cable D-66 loaded as a function of both frequency and end-section length. At 3000 cps the characteristic impedance for the 22-D-66 is 1270-j80 ohms for the 0.5 end-section while at 0.8 it becomes 994-j563 ohms. Therefore when making structural return loss measurements, end-section lengths must be known accurately since they can affect the results of the measurements in a major way.

2.322 It should be borne in mind that REA TE & CM-431, "Voice Frequency Loading for Trunk Cables," and REA TE & CM-424, "Design of Subscriber Loop Plant", require that plant be designed and built on the basis of 0.5 end-sections or 2250 feet for D-66 loading. Other applicable REA Telephone Engineering and Construction Manual sections dealing with attenuation and reflection losses of loaded cables have been prepared on the basis of 0.5 end-sections or mid-section impedances.

2.4 Short Rules to Remember:

2.41 If a loaded cable is infinite in length (in practical terms, 15 db or longer one-way attenuation at 1000 cps) what happens to its far-end terminal has no effect on the impedance seen at the near-end terminal. This means that the termination at the far end can vary, for example, from 100 million ohms to one ohm (actually from an open to a short) and this does not change the value of the near-end impedance.

2.42 The mid-section impedance of a loaded cable which is infinite in length means the impedance of a loaded cable when looking into it from an end-section which is one-half the length of a full loading section and whose far-end section is also one-half the length of a full section.

3. THE PRECISION BALANCING NETWORK

3.1 The successful performance of negative resistance (E-6 type), negative impedance (E-23 type) and hybrid voice frequency repeaters depends not only on their design characteristics but also on the electrical characteristics of the plant facilities over which they are to operate. Fundamentally, good performance depends on the degree of match possible between the plant impedance and the repeater network impedance at all frequencies. Though in the case of hybrid-type repeaters operating on a two-wire basis transmission within the repeater amplifiers is unidirectional (two separate amplifiers required, one in each direction of transmission) while in the negative resistance and impedance type it is bidirectional, both modes of operation depend on proper impedance match between their respective impedance networks and the plant impedance. Essentially, the better the impedance match, the more repeater gain is possible. Devices which make this match possible are precision balancing networks more commonly known as balancing networks.

3.2 Two-terminal networks which very closely simulate the impedance of the type of plant over which voice frequency repeaters are intended to operate, over the entire frequency range of interest, are termed Precision Balancing Networks and abbreviated PBN. Precision balancing networks which simulate the impedance of two types of loading systems (D-66 and H-88) at all frequencies of interest are an integral part of the equipment required for making the structural return loss measurements described herein.

3.21 Fig. 3 shows the configuration of the REA design for a precision balancing network which matches the mid-section impedance of 19, 22 and 24 gauge exchange type cable D-66 loaded (its impedance is shown in Fig. 1). The design shown in Fig. 3 can be conveniently made up if the parts, to the values shown, are locally available. The C-115DL precision balancing network made by the Ceeco Company or the Communication Apparatus Corporation type 115DL or its equivalent may also be used.

3.22 The W. E. Co. 115H or the Ceeco C-115H PBN's are used for 19 and 22 gauge cables H-88 loaded. For 24-H-88 loaded cable the W. E. Co. type 115AL PBN must be used.

3.3 Short Rules to Remember:

3.31 A precision balancing network is a two-terminal device which simulates the impedance of an infinitely long loaded cable over the entire frequency range of the loading system.

3.32 A loaded cable which is finite in length (all applications encountered in common practice are included under this definition of finite) can be made to have its impedance look like the impedance of a loaded cable which is infinite in length. This can be done by connecting a precision network at the far-end terminals of the cable; the impedance seen at the near-end terminals is now the infinite line impedance. In addition, if the end-section at the near-end is 0.5, the resulting impedance is termed the mid-section characteristic impedance or the mid-section infinite line impedance.

4. WHAT IS STRUCTURAL RETURN LOSS (SRL)

4.1 Fig. 1, which displays the mid-section infinite line impedance characteristics of 22-D-66 cable shows a uniform curve at all frequencies with no evidence of even minor impedance irregularities. This is as it should be, since the assumptions on which the derivation of this curve have been based assume the loaded cable pair in question to have ideal characteristics, that is:

a. The cable mutual capacitance for each 4500 feet loading section (6000 feet for the H-88) is precisel the same.

b. The loading coil inductance at each load is precisely the same.

c. The physical distance between each two consecutive load coils is precisely 4500 feet (6000 feet for the H-88).

4.2 In an actual loaded cable the above factors cannot be made ideal due to practical considerations relating to manufacture and construction. Some of these are:

a. Variation of cable pair mutual capacitance mainly from pair to pair and from reel to reel.

b. Variation of coil inductance from loading coil to loading coil.

c. Practical staking, construction and maintenance problems do not permit placing loading coils at exact specified intervals.

4.3 To the extent that the cable pair mutual capacitance, the loading coil inductance and load coil spacing all may depart from their assigned value and that the variables in question may occur in any random manner and relative degree, the smooth impedance characteristic of Fig. 1 has now been somewhat altered. These small impedance variations compared to the ideal impedance result in small reflection currents which eventually reach the near-end or point of measurement. The overall value of these small reflected currents is known as structural return loss and is usually expressed in db. The greater the reflection current the lower will be the structural return loss in db and the poorer the circuit performance will be. An ideal cable which has not even small irregularities has zero reflected currents and therefore its structural return loss is infinite. Structural return loss therefore is a figure of merit of the completed cable plant with regard to impedance uniformity and it reflects the quality of uniformity (or lack of it) in the mutual capacitance of the cable product, the quality of uniformity (or lack of it) in the inductance of the loading coil product and the care with which the plant has been staked and loading coils accurately placed (or lack of accuracy). The greater the care and better the methods used to build plant the higher the figure of merit of the plant will be and the higher the structural return loss. High values of structural return loss mean plant with high performance capability.

4.31 Strictly speaking, the structural return loss of a loaded cable is an index of the departure of the impedance of the actual circuit under measurement from the ideal characteristic impedance. Since, however, the precision balancing networks discussed in this section precisely simulate the ideal characteristic impedance, the structural return loss is taken as the balance between the cable circuit under test and its corresponding precision balancing network used for the test.

4.4 Since the structural return loss is dependent on the random combination of a large number of small reflected currents due to the factors in paragraph 4.2 above and in addition the phase of the reflected currents vary with frequency, the resulting structural return loss displays peaks and valleys over the frequency range measured. Examples of actual loaded cable pairs shown in Figs. 20-30 show the peak-and-valley-frequency effect. Structural return loss values are extremely high. This is indicative of cable plant with good figure of merit and therefore containing very small random irregularities.

4.5 An examination of the SFSRL plots in Figs. 20-35 will indicate that there is some frequency where the value of the SRL is the lowest. This frequency together with this lowest (worst) SRL value within the 300 to 3000 cps range is known as the Critical Frequency Structural Return Loss (CFSRL). It is this value of CFSRL in REA TE & CM-444, "Calculation of Net Loss of Negative Impedance Repeatered, Loaded Trunks", and REA TE & CM-446, "Design of Two-Wire D-66 Loaded Negative Resistance Repeatered Trunk Plant", which is used to compute repeater gains. For example, reference to Fig. 20 shows the CFSRL value to be 35.2 db at the critical frequency of 2400 cps.

4.51 Important Note: In Figs. 20-30 the critical frequency structural return loss is also shown for a frequency range between 300 to 3400 cps, indicated as "3400 cycle band". With the D-66 loading system the cutoff frequency is well beyond 4500 cps and this means that a frequency band up to 3400 cps can be quite usable. The present voice frequency repeater equipment and 500 type telephone sets transmit well up to 3400 cps. Further, many new trunk carrier systems are now being engineered for a 300 to 3400 cps band while others are being modified for improving their bandwidth characteristics. Therefore, when making acceptance tests on D-66 loaded cable plant, not only the 3000 but the 3400 cycle band CFSRL should be recorded.

4.6 Single Frequency Structural Return Loss (SFSRL)

4.61 As discussed in paragraph 4.31 above the essential factor when making structural return loss measurements is that the cable pair at its far-end, and at the test hybrid on its network side must each be terminated in precision networks which match the impedance of the cable over the entire frequency range of interest to be measured. Therefore, measurement under precision network terminations constitutes a structural return loss measurement. In addition, if the measurements are made with conventional single frequency oscillator and AC-VTVM equipment, using point-by-point techniques measuring each frequency separately, the measurements are further termed single frequency or SF. Structural return loss measurements using point-by-point methods are termed Single Frequency Structural Return Loss or SFSRL. Paragraph 4.5 above refers to SFSRL type of measurements.

4.62 Devices of the single frequency oscillator and AC-VTVM type are available which measure the entire frequency range of interest in a loaded cable by sweeping through the entire range. Such equipment is known as Swept-band Oscilloscopes or Level Tracers and make possible substantial simplifications in testing. Their use is discussed in paragraph 7.2 below.

4.63 The step-by-step measurement procedures for making the SFSRL measurements are discussed in paragraph 8.

4.7 Echo Structural Return Loss (ESRL)

4.71 In addition to the point-by-point, single frequency procedures of paragraph 4.6 above other methods are available which measure the structural return loss by a single measurement only. This is accomplished by a source of random noise which replaces the single frequency oscillator and a noise measuring set, replacing the AC-VTVM. The energy from the noise generator is evenly distributed throughout the voice frequency range. That is, all frequencies are present at the same time and approximately in the same amount of power. Because the noise source generates a wide band of frequencies, a network is provi d to shape its output to match the frequency characteristics to normal message telephone channels. The ba... of frequencies used for this purpose range from 500 to 2500 cps.

4.72 The "echo" band in a message telephone circuit is considered to occupy the frequency range between 500 to 2500 cps.[1] It is thought to be representative of the frequencies which are important during talking conditions. Structural return loss measurements made with random noise equipment in this frequency range are classed Echo Structural Return Loss Measurements and abbreviated ESRL. The generator used to supply the random noise is the W. E. Co. 201B Noise Generator using a 455B weighting network or the Northeast Electronics Company type TTS 56. The detector used to measure the returned noise power is the W. E. Co. 3A Noise Measuring Set using C-message weighting or the Northeast Electronics Company type TTS 37B or equivalent.

4.73 The step-by-step measurement procedures for making the ESRL measurements are discussed in paragraph 8.

5. THE HYBRID AND THEORY OF OPERATION

5.1 Throughout the above mentioned discussion of structural return loss the existence of a device capable of measuring this quantity has been tacitly assumed. This device is the hybrid coil or more generally known as the hybrid. While the hybrid may be described in various ways, it accomplishes the basic function of separating the two directions of transmission in an otherwise bidirectional transmission medium. That is, it provides with other associated equipment, a means for the transmit and receive branches of a circuit which are fundamentally derived on a four-wire basis to be routed over the same two-wire bidirectional line with emphasis on keeping the interaction to a minimum. It should be noted that resistors may also be used as elements for performing a hybrid-type function.

5.2 The hybrid is an indispensable component of the telephone plant. Due to its inherent capability of providing direction-of-transmission separation it did in fact make the introduction of electronic amplification in telephone plant possible and in this respect made long distance communication possible. The uses of the hybrid are many and varied. Some of the more prominent hybrid applications are listed below.

[1] AT&T Company's "Notes on Distance Dialing", 1961, Section 6.

5.21 In the Telephone Set. To separate the "transmitter" from the "receiver" branch.

5.22 On Two-Wire Operation of "V" Type Repeaters. To separate the four-wire transmission within the repeater from the two-wire line, where two-wire-line transmission is involved.

5.23 On Four-Wire Operation of "V" Type Repeaters. To combine the four-wire-line transmission to the user's two-wire telephone line. A hybrid operating in this manner is often known as a Four-Wire Terminating Set.

5.24 In Carrier or Multiplex Radio Circuits. All carrier derived circuits whether transistorized or vacuum tube, trunk or subscriber, open wire or cable, operate essentially on a four-wire basis. That is, each direction of transmission is electrically separated from the other direction. Hybrids are used for routing both directions of voice frequency over the same two-wire line. In this respect, it is similar to the "V" type repeater described in paragraph 5.23 above.

5.25 Terminal Balance for VNL Circuits. Intertoll trunks, designed according to present transmission practices operate at very low net losses. To make this possible without objectionable echo or singing an extensive degree of balancing must be applied. Of the devices used for making this possible, the hybrid is an integral part.

5.26 Measurement of Return Loss. This may include the return loss of two dissimilar impedances, the degree of terminal balance of a toll center, the return loss characteristics of a subscriber loop or generally any measurement which seeks to establish the degree of balance or match between the quantities under consideration.

5.3 Figure 5 shows several examples where hybrids are required for the application intended, while Figure 6 shows some of the different types of hybrids in use.

5.31 In examining the manner in which the hybrid accomplishes its intended function, the Wheatstone Bridge analogy offers a convenient means of explanation. For example, the four arms of the bridge can be thought of as the four essential elements normally associated with the hybrid. These are:

A. The "transmit" branch.

B. The "receive" branch.

C. The two-wire line branch.

D. The network branch.

Fig. 7 shows the Wheatstone Bridge equivalent of the hybrid circuit and all of its associated components.

5.32 In Fig. 7, when the arm R_1 equals arm R_2 and arm R_N equals R_W, there is no difference of potential across the galvanometer terminals (G) and therefore no current flows through it. The galvanometer therefore is at a null or the bridge is balanced. If arm R_1 still remains equal to arm R_2 but arm R_N is not equal to arm R_W then there is a difference of potential across the galvanometer terminals and a current flows through it. This is a current caused by the unbalance and its magnitude is determined simply by the degree of mismatch between R_N and R_W.

5.33 In Figs. 7B and C the basic Wheatstone Bridge circuit is applied to the operation of the hybrid coil. For this reason the battery has been replaced by an oscillator, the galvanometer by a detector or transmission measuring set and the resistors with impedances. When Z_1 equals Z_2 and Z_{net} equals $Z_{2\text{-wire line}}$ there is no difference of potential across the detector terminals and therefore no current flows through it. The detector is therefore at a null or the bridge is balanced. When Z_1 still equals Z_2 but Z_{net} is no longer equal to $Z_{2\text{-wire line}}$ there is a difference of potential across the detector terminals and a current flows through it. This is a current caused by the unbalance and its magnitude depends on the degree of mismatch between Z_{net} and $Z_{2\text{-wire line}}$. If the degree of the impedance match, measured as mentioned above, is that of a loaded line and its respective precision balancing network, the measurement is basically structural return loss which this section shows how to make.

5.4 The above discussion has served to provide a general understanding of the hybrid operation. In the paragraphs below, a more thorough explanation is now given by reference to Fig. 8 which shows a coil type hybrid having connected to its appropriate terminals an oscillator, a detector, a network and two-wire line which match the impedances for which the hybrid has been designed. The resulting hybrid action when changes take place in certain of the hybrid terminals is as follows:

5.41 If the line contains no irregularities, the signal from the oscillator terminals causes equal current to flow in the Two-Wire Line and Network and no current enters the Detector. That is, one-half the power delivered by the Oscillator to the hybrid coil goes to the Two-Wire Line and the other half to the Network. Therefore there is a 3 db (3.01 db to be more exact) loss between the Oscillator and the Two-Wire Line.

5.42 If however, the line contains irregularities, part of the energy on the Two-Wire Line (which is already 3 db down) re-enters the hybrid. Again, one-half of this returned energy goes to the etector and the other half to the oscillator. Therefore there is a 3 db loss between the Two-Wire Line nd the Detector. Thus the total hybrid transmission loss between the Oscillator and Detector is 3+3 db r 6 db.

5.421 The 6 db transmission loss between the Oscillator and Detector above assumes an "ideal" coil hybrid; that is one which does not have iron or copper losses. With practical hybrids (that is, ade out of physical components) these copper losses usually amounting to 0.25 to 0.5 db must be dded twice to the above 6 db thereby making the actual loss about 6.5 to 7.0 db (say 7.0 db).

5.422 The transmission loss of 7.0 db through the hybrid, in the presence of line irregularities, must not be confused with the structural return loss, though inherently the measurement of the tructural return loss includes this 7.0 db automatically. Stated in another way, when making the tructural return loss measurements, this 7.0 db loss characteristic of the hybrid coil must be accounted or (subtracted).

5.43 In Fig. 8, if the hybrid terminals where the Two-Wire Line is connected are open-circuited or short-circuited the resulting transmission loss through the hybrid will be 6.5 to 7.0 db as above. This s because the power division within the hybrid coil as described in paragraph 5.41 still takes place but n addition there is now a return loss between the impedance of the Network and the open or shorted terminals f the Two-Wire Line side of the hybrid which must be added. This return loss however is 0 db so that the otal loss again is 6.5 to 7.0 db. Note: When making the actual measurements, described in paragraphs 7 nd 8 the trans-hybrid loss is automatically accounted for at all frequencies of measurement during the alibration procedure.

5.44 Another significant property of the coil hybrid indispensable in singing point work (for determining available gain of "V" type repeaters) but mentioned here only for completeness is that if the Network erminals of the coil hybrid are alternately opened or shorted while the Two-Wire Line hybrid terminals are eing shorted or opened, the coil hybrid acts as though it were essentially a repeating coil. The only ransmission loss incurred is the normal insertion loss of the coils.

. PRINCIPLE UNDERLYING THE MEASUREMENT OF STRUCTURAL RETURN LOSS

6.1 Fig. 8 shows the connections of the test equipment and cable pair under test for the measurement of the cable structural return loss. By reference to this figure the principle underlying the structural eturn loss measurements can now be summarized as follows:

The coil hybrid acts as an a.c. bridge. In this bridge:

A 600 ohm oscillator and a 600 ohm detector make up two of the arms of this bridge. Since their impedances are equal and at 600 ohms, they do not directly enter into the measurement of the structural return loss.

The precision balancing network on one side of the hybrid and the cable pair under test terminated in a similar precision balancing network on the other side make up the remaining other two sides of the bridge. It is the variations in these two sides of the bridge which give rise to the structural return loss.

Now, precision balancing network (A) precisely matches precision balancing network (B). If in addition, the cable under test precisely matches precision balancing network (B), these two arms of the bridge are perfectly balanced, there is no reflected energy, no current flows through the detector, the detector reads zero and therefore the structural return loss is infinite.

If the cable under test contains irregularities its impedance does not match network (B) and the two arms of the bridge are unbalanced, energy is returned to the hybrid, current flows through the detector and a finite reading is obtained. This reading corresponds to the value of the structural return loss at the frequency of measurement.

. REQUIRED TEST EQUIPMENT

7.1 The following type and number of measuring equipment is required for making the SFSRL measurements in D-66, H-88 and D-66/H-88 loaded cables:

7.11 Two W.E. Co. 120P or Altec Lansing Co. 15189 repeating coils wired as per Figure 9 for making up coil test hybrid or Ceeco Co. type C-101A Test Hybrid or other equivalents.

7.12 One, Hewlett Packard Co. type 204B, 200CD, 200J oscillator or equivalent.

7.13 One, Hewlett Packard Co. 403B, A, 400D, H, L AC-VTVM or equivalent.

7.14 One, 600 ohm, ± 1%, 1 watt carbon resistor on double banana plug.

7.15 Two precision networks for 19, 22 or 24 gauge D-66 loaded cables. REA design of Figure 3 or Ceeco Co. type C-115DL, or CAC Co. type 115DL.

7.16 Two precision networks for 19 or 22 gauge H-88 cables, W. E. Co. type 115H, or Ceeco Co. type C-115H or C-100 Test Set or equivalent. Two precision networks for 24 gauge H-88 loaded cables, W. E. Co. type 115AL.

7.17 Two decade capacitor boxes, Ceeco Co. type C-100 Test Set or Heath Co. type DC-1 or Precise Co. Type 478.

7.2 Oscilloscopic equipment of the swept frequency type, also known as Level Tracers, can be used for making the SFSRL measurements which very substantially reduces the measurement time and effort. The Siemens-Halske Co. type Rel 3K 211b Level Tracer and the Hallamore Co. type TMS-0100 of Swept Band Set can be used. The Siemens-Halske type Rel 3K 211b Level Tracer can be used for both the H-88 and D-66 loaded cables since its upper frequency limit is 6000 cps. The Siemens Level Tracer also contains a built-in hybrid, thereby eliminating the need for the external hybrid discussed in paragraph 7.11.

7.3 The following type and number of measuring equipment is required for making the ESRL measurements in D-66, H-88 and D-66/H-88 loaded cables:

7.31 Hybrid, precision network and capacitor building-out equipment as per paragraphs 7.11, 7.15 (and 7.16) and 7.17, respectively.

7.32 One W. E. Co. 201B Noise Generator with 455B Network, or N. E. Electronics Co. TTS-56 or equivalent.

7.33 One W. E. Co. 3A Noise Measuring Set or N. E. Electronics Co. TTS-37B or equivalent.

8. STEP-BY-STEP MEASUREMENT PROCEDURE

8.01 The type of test equipment, equipment connections, calibration and measurement procedure for D-66, H-88 and D-66/H-88 loaded cables are shown in Figs. 10-14 for the SFSRL measurements and Figs. 15-19 for the ESRL measurements. The discussion in paragraphs 8.1 and 8.2 below apply directly to the SFSRL measurements. Paragraph 8.5 discusses ESRL considerations.

8.1 Frequency Range Which Must Be Measured

8.11 The band of frequencies which must be measured is from 200 cps to 4500 cps for D-66 and up to 3500 cps for H-88 and D-66/H-88 compensated cables. The critical frequency structural return loss, abbreviated CFSRL, is the lowest value of structural return loss between 300 and 3000 cps. It is this value which is used in carrying out the repeater circuit design when computing available repeater gain and the resulting net loss.

8.2 Sending Level and Calibration for SF Measurements

8.21 Because the test equipment setup is calibrated to produce 0 dbm (zero dbm) on the detector when the hybrid "Line" terminals are short-circuited, the direct reading of the AC-VTVM in minus dbm is the actual value of structural return loss in db when making the measurement and no other correction to the meter reading is needed. This is illustrated in Figs. 10-14.

8.22 The above calibration procedure for setting the oscillator output level to produce 0 dbm on the AC-VTVM when the hybrid "Line" terminals are shorted is but one method for calibrating out the transhybrid loss. That is, the power division loss which is inherent in every coil type hybrid and is 3 db in each direction plus core losses of 0.3 to 0.5 db or approximately 7.0 db total. This transhybrid loss must not be charged to the measurement and for this reason it is calibrated out.

8.23 The same result can be obtained by calibrating out from the measurement the 7 db transhybrid loss by using an alternate method. This is to connect the 600 ohm oscillator directly into an external 600 ohm resistor and set the oscillator output level to read +7 dbm on the AC-VTVM across the external 600 ohm resistor. Either calibration method will give the same results. When using this method the SRL in db is again the direct reading of the AC-VTVM in minus dbm. For example, with the cable connected if the reading of the AC-VTVM is -29 dbm, at a given frequency, the SRL value is 29 db at the same frequency.

8.24 There can be many calibration levels which can be used which will give the same overall results. The reason that the method of paragraph 8.22 or 8.23 is used is because they are simple and allow the readings to be direct. No corrections are necessary and this saves time. Sometimes it also eliminates simple mistakes such as adding or subtracting. But if for some reason other calibration levels are necessary, good results can still be obtained. For example, if the calibration is performed as follows: Connect the 600 ohm oscillator directly into the external 600 ohm load and set the oscillator output level for the AC-VTVM which is connected across the 600 ohm resistor to read 0 dbm (zero dbm). Now when the oscillator (with its output level control unchanged) is connected into the hybrid and the SRL measurement is made, the readings in the AC-VTVM will no longer be direct. Because the 7 db (approximately) transhybrid loss has not been accounted

for in the calibration the readings on the AC-VTVM will be lower (SRL will look better by 7 db) so that 7 db must be subtracted from the SRL reading. Assume, for example, when using this calibration method the AC-VTVM reads -32dbm when the measurement is made. This means that the SRL reading is 32 db but the correct value of SRL is 32 -7dbm or 25 db. Assume that the calibration level for the same example has been -10 dbm for a valid reason. When the SRL measurement is made this means that 10 + 7 or 17 db must be subtracted from the meter reading to obtain the correct SRL value!

8.25 Some of the more important reasons for calibrating at levels lower than that of paragraph 8.11 may be to avoid possibility of inducing interference into other working pairs or the test equipment may not be capable of delivering the +7 dbm required for the direct (no correction) measurement. The type of equipment shown herein is capable of an output level of +7 dbm into an external 600 ohm resistor so that this will not be a problem.

In summary, any calibration method can be used and will give good results if one is careful to make the appropriate corrections in the meter readings. The methods of paragraphs 8.22 and 8.23 are direct and do not require corrections; whatever the meter reads, that is the answer also. The calibration methods of paragraphs 8.21 and 8.23 are used in Figs. 10-14 and all SFSRL examples herein.

8.3 Sending Level and Calibration for Echo Measurements

8.31 The discussion in the above paragraphs for SFSRL measurements apply equally well to the ESRL measurements with regard to the 7 db transhybrid loss and calibrating levels. The detector equipment, however, used in the ESRL measurements is calibrated in different units; namely dbrn-C. For this reason some modification of the terminology is necessary and a brief explanation of this is given below:

8.32 The 3A NMS will read 0 dbrn-C in "N_M-600 ohm", "Flat" or "C-Message Wt." position when a test tone of -90 dbm at 1000 cps is applied to its input terminals and 90 dbrn-C with a 0 dbm, 1000 cps test tone. Single frequency test power inputs at frequencies other than 1000 cps are properly weighted by the 3A NMS when in the "C-Message Wt." position, according to frequency. When the 201B Noise Generator is set for an output of 0 dbm power the corresponding reading on the 3A NMS C-Message Wt., is approximately 90 dbrn-C when the two are directly connected. If the noise generator, set for the same output power, is now connected through the hybrid for the ESRL measurement (PBN connected on one 2-wire side of the hybrid with the other side open or shorted) the new reading on the 3A will be approximately 83 dbrn-c. The 7 db reduction in power is the transhybrid loss due to the coil hybrid. To account for the 7 db transhybrid loss the Noise Generator output is set for +7 dbm (97 dbrn-C directly into the noise generator) which is approximately 90 dbrn-C when connected with the test hybrid in the calibrate position. In the measuring position, when the cable pair under test is connected to the hybrid terminals the reading on the 3A NMS becomes lower. The difference between the 90 dbrn-C in the "calibrate" position and the new dbrn-C reading in the "measure" position is the ESRL value in db.

8.4 Correct Settings for Precision Balancing Networks

8.41 A discussion is given of the components in a precision balancing network (abbreviated PBN) used in the measurement because if improperly connected or used it can lead to SRL measurements which are not correct. The PBN used in the measurement consists of three parts:

a. The basic network

b. Components for making the end-section variable for H-88 loading only.

c. Components for changing the gauge from 19 to 22 or 24.

8.42 The basic network in (a) consists of capacitors, inductors and resistors to simulate D-66 loading with 2250 feet end section (0.5 or mid-section impedance) but only 900 feet end section for H-88 loading. These components are permanently connected and not externally accessible for changing.

IMPORTANT NOTE: THE REASON THAT THE D-66 BASIC NETWORK IS A FIXED 2250 FEET IS BECAUSE D-66 LOADED TRUNK CABLES ARE ENGINEERED TO HAVE 2250 FOOT END SECTIONS (0.5 END SECTIONS). EXISTING H-88 CABLES ON THE OTHER HAND, ARE FOUND WITH MANY END SECTION LENGTHS AND THE BASIC NETWORK IS THEREFORE MADE VARIABLE TO ACCOMMODATE THIS.

8.43 As pointed out in paragraph 8.42 above, for D-66 loaded cables the basic end section of the precision network is 2250 feet without any additional building-out capacitor. For H-88 loading, a variable capacitor (CBO) is provided with the basic network for building-out to the particular length of the end section of the cable. The capacitance of both this CBO in the PBN in microfarads (or feet) plus the basic network equivalent capacitance determines the total end-section value of the PBN. For example, to set a D-66 PBN to have a total end section of 0.5 (2250 feet) the amount of CBO required is:

2250' -2250' = 0 feet, additional

To set an H-88 PBN to have a total end section of 0.5 (3000 feet) the amount of CBO required is:

3000' -900' = 2100 feet, additional

This 2100 feet is strapped in building-out capacitor CBO1 shown in Figs. 13-14 and 18-19 for H-88 loading.

8.44 Resistors and capacitors are also included in the PBN for the correct cable gauge. In D-66 loaded cable the same PBN is used for 19, 22 and 24 gauge exchange type cables. For H-88 loading the same PBN can only be used with 19 and 22 gauge exchange type cables. For 24 gauge, H-88 loaded, a separate network must be used (W. E. Co. 115AL). For D-66 PBN's the gauge is readily set by a simple strap or by a switch which selects the desired gauge. For H-88 PBN's this is not possible. The gauge terminals are numbered and the numbers are different for the various manufacturers. For this reason, for H-88 loading, consult the instructions of the manufacturer for the particular PBN used in the measurement.

8.45 The terminals of the PBN which connect to the "NET" side of the hybrid are normally numbered 1 and 2 for the particular type of units shown herein. The CBO where used is also strapped across the same terminals 1 and 2. (Consult the instructions of the manufacturer if other type of PBN is used for the actual terminal numbering - they can be different.)

8.46 As discussed in paragraph 8.4 above, because D-66 loaded trunk plant is engineered and built for 2250 feet end sections the structural return loss measurement is made with D-66 PBN's having 2250 feet end sections. The Ceeco (Communication Equipment and Engineering Company) type C-115DL PBN and the CAC (Communications Apparatus Corporation) type 115DL PBN are networks with such built-in 2250 foot end sections. For this reason the additional building-out capacitor shown as CBO1 in Figs. 13-14 and 18-19 for H-88 loading is not required with D-66 loading. In Figs. 10-12 and 15-17 for D-66 loading no CBO1 capacitor is shown in the PBN.

8.47 For H-88 loading or for measuring at the H-88 end of a D-66/H-88 loaded cable the basic PBN end section is 900 feet. This was discussed in paragraph 8.42 and in the example given in paragraph 8.43. For making measurements therefore on H-88 cables having 0.5 end sections (3000 feet) additional capacitance is required in the basic H-88 PBN. This is the function of capacitor CBO1 shown in Figs. 13-14 and 18-19. The value of this capacitor is set as follows:

Basic PBN Capacitance	=	900 feet
Total Required Capacitance	=	3000 feet
Difference	=	2100 feet

Therefore, before proceeding with the measurement, capacitor CBO1 is set for 2100 feet because this represents a capacitance value of 0.033 microfarads based on 0.083 microfarad per mile cable.

8.48 Having connected the PBN's 1 and 2 for 0.5 end sections, as discussed above, the SRL measurement is made and the results entered in the "Data Sheets".

8.5 Maximizing the Structural Return Loss

8.51 The structural return loss measurement made with the PBNS' set for 0.5 end sections as described above does not normally yield the best structural return loss which the loaded cable is capable of. Though the measured value may be sufficiently high the actual value itself may be even better than this. In other cases the results of the measurement may be indicative of an apparent poor return loss in the outside plant. The reasons for this are as follows:

a. The cable may not be exactly 0.5 end section in physical length but somewhat longer or shorter than this.

b. The mutual capacitance at the end section of the pair under test may be somewhat larger or smaller than 0.083 microfarads per mile.

c. For existing plant both the pair capacitance at the end section and its physical length can vary from standard values and further the values themselves may be different than present objectives in use.

d. Shortening or lengthening of the end section due to relocations, highway crossings, etc.

e. Minor amounts of moisture or other contamination in the cable end section.

8.52 To assure that the values measured are the best values possible, "maximization" is used. That is, that value of structural return loss is determined which gives the best performance, so to speak, possible from the outside plant. Maximizing the structural return loss is accomplished by means of an external variable capacitor shown as C2 in Figs. 10-19. By this means, such adverse factors as those discussed in paragraph 8.51 (a) to (e) above, which would tend to degrade the value of structural return loss, are eliminated. The actual procedure for accomplishing this is discussed in paragraphs 8.521 to 8.524.

8.521 An additional variable capacitor (shown as capacitor C2 in Figs. 10-19) should be connected across the "Line" terminals of the hybrid, that is, directly across the cable pair. Vary this capacitor. If this improves the SFSRL or ESRL (particularly in the 2500 to 3000 band for SFSRL measurements as discussed in paragraph 8.524 below), this means that the end-section at the hybrid location is electrically shorter than 0.5 though in physical lengths at 0.5. Capacitor C2 should be varied until the optimum value of SRL is obtained and the data recorded in the Data Sheets. Use this value of SRL instead of that obtained in paragraph 8.48 above using the 0.5 end sections.

8.522 If the variable capacitor across the cable pair as discussed in paragraph 8.521 above results in poorer values of SRL for either SFSRL or ESRL measurements (again, particularly in the 2500-3000 cps band for the SFSRL measurements) than the values of paragraph 8.48 above this means that the end-section at the hybrid location is electrically longer than 0.5 though in physical length at 0.5. Remove this capacitor from the "cable" side of the hybrid and connect it to the "net" side of the hybrid, that is directly across PBN No. 1 terminals 1 and 2. This is shown as capacitor C1 in Figs. 10-19. Vary this capacitor (connected across the "net" hybrid terminals) until the optimum value of SRL is obtained and record this value of SRL in the "Data Sheets". Use this value of SRL instead of that obtained in paragraph 8.48 above.

8.523 Finally, if this building-out capacitor connected on the "Line" terminals of the hybrid (across cable) or across the "Net" hybrid terminals (across PBN No. 1) lowers the value of SRL as obtained in paragraph 8.48 above this means that the end-section adjacent to the hybrid is not only 0.5 in length, but also 0.5 electrically (which is really the important consideration) and the SRL values measured in paragraph 8.48 are the optimum values.

8.524 The above procedure for adjusting the end-sections result in obtaining the "best possible" or optimum value of SRL. When making the actual SFSRL measurements, the decision as to "when" the "best possible" or optimum SRL has been obtained will not be one-hundred percent clear cut and some adjustment will be required. This is because each time the value or position (with respect of the hybrid) of the building out capacitor is changed the entire waveshape of the SRL will also change. At some frequencies where the SRL was better, it may now become worse while at other frequencies the reverse will occur. However, at some important range of frequencies the SRL will improve and this is what the CBO procedure is intended to accomplish. In SFSRL measurements this frequency band of interest is the 2500 to 3000 cps range because in a 3 kc/s band, this range would offer the greatest possibility for repeater singing problems. On the other hand, when using this procedure the CBO must not degrade unduly the remaining frequency band from 300 to 2500 cps. For example, this lower band should remain at an SRL level higher than the 2500 to 3000 cps band. Again judgment will be required on this. Experience in making these measurements will make the selection of the optimum condition relatively easy. The above comments are not applicable to the ESRL measurements. There, a given amount and location of CBO will either improve or degrade the return loss. The CBO resulting in the best ESRL should, of course, be recorded.

8.6 Location Which is Controlling on the Measurement

8.61 The effect of the far-end PBN (or No. 2 PBN) normally is not as controlling on the values of the SRL which are measured at the sending-end. This is because the attenuation tends to mask small irregularities at the far end as a result of PBN No. 2 not precisely matching the cable end-section at that end and by the time this small irregularity arrives at the sending-end its value is high so that it does not change the value of SRL in any significant way. The above holds only when the circuit attenuation is substantial, 8 to 10 db or higher. If the circuit attenuation, however, is 5 to 8 db or lower the far-end will effect the sending-end SRL. For this reason, the CBO at the PBN No. 2 location (shown as CBO2 in the H-88 examples and C3 in the D-66 examples) must be varied also until the optimum SRL is obtained at the sending-end. Regardless of the circuit attenuation, it is advisable at the end of the measurement steps discussed in paragraphs 8.4 to 8.5 above to vary the C3 (or CBO2 for H-88 loading) at the far-end until the optimum SRL has been obtained at the sending-end. This optimum SRL is the SRL values which should be recorded in the "Data Sheets". It is obvious, of course, that if the measurement location is reversed, the far-end section PBN which was not of extreme importance before will now be the controlling factor. The above considerations are applicable equally to SFSRL and ESRL measurements.

8.7 Treatment of Mixed Cable Gauges

8.71 Cables which are uniform in gauge, that is, all 22-gauge D-66 or all 19-gauge H-88, etc., for the entire circuit length will be much easier to measure for SRL than cables of mixed gauges. The measurement of mixed gauges is discussed in paragraph 8.72 below. For uniform gauge cables the only adjustment which may be required during the measurement will be in the capacitance of the end-section adjacent to the hybrid location resulting in the "optimum" value of SRL for the particular cable under test. The procedure for accomplishing this is discussed below.

8.72 Due to the measuring complexity which mixed gauges present, it is recommended that when the measurement is made the PBN gauge settings be changed alternately from one gauge to the next starting with the sending-end PBN and then with the far-end PBN until the combination in gauges is found which yields the optimum SRL which is possible for the particular layout. This procedure applies equally to SFSRL and ESRL measurements.

8.8 Use of Level Tracer Equipment

8.81 Where the cable to be measured consists of only one uniform gauge and where the end-sections are close to 0.5 in length it will be found that the measurement becomes relatively simple using the single frequency techniques and the test equipment shown in Figs. 10-14 herein. Where the end-sections are longer or shorter than 0.5 and/or where mixed gauges are involved the measurement complexity and the time required increases. This is because especially with SFSRL or point-by-point measurement techniques each time a change is made, for example, in end-section CBO, PBN gauge, etc., the entire frequency band must be plotted and the comparison made to see if this change has improved the SRL. Thus, for SRL measurements the major disadvantage becomes one of time, but the results of point-by-point measurements are nevertheless valid.

8.82 The above type of SFSRL measurements become relatively simple if swept-band type oscilloscopes are available for use. These devices allow the entire band to be observed at a glance. The result of anyone adjustment or adjustments during the measurement procedure can be immediately seen and analysed. Thus, the conditions which give optimum SRL can now be accurately pinpointed. Because such swept-band devices greatly facilitate measurements they should be used whenever they are available. The Siemens-Halske Rel 3K 211b Level Tracer of the Lear/Siegler Swept-Band Oscilloscopes can be used with good results. Typical measurement examples when using the Siemens-Halske Level Tracer are shown in Figure 35.

8.9 Other Important Considerations

8.91 The structural return loss measurements must be made at the location where the repeater equipment will normally be located and operated. For example, in a toll connecting trunk application where the terminal repeater will be located at the Class-5 office, the structural return loss measurement must be made from that office. That is the test hybrid must be located at the office where the repeater will be located. Where repeaters will be located at each of two terminal offices measurements must be made from each office for the same cable. In intermediate repeater applications the measurements must be made from the repeater location but looking in each cable direction.

8.911 It is advisable that measurements on the same cable be made in each direction. This helps detect irregularities which may still be present but which the measurement from one end only may not reveal. This comes about from the intervening circuit attenuation. If the attenuation is appreciable, say 12 db at 2800 cps, the round-trip circuit attenuation will be at least 24 db, even though the far-circuit end may be open or shorted, and this will also be the minimum value of SRL at the measuring end. In other words, if an irregularity exists which is far from the point of measurement the intervening attenuation will mask it and reflect it as a fairly good value of SRL at the measuring point. To assure against this occurring if the measurement is now made from the opposite end, the value of SRL will be much lower (less masking attenuation) and thus much easier to detect.

8.92 Prior to making measurements on D-66/H-88 loaded cables joined by the D-66/H-88 junction impedance compensator (For the configuration of the junction compensator refer to REA TE & CM-431, Fig. 1) assure by checking that the compensation is properly designed and correctly inserted into the cables. That is, that the proper value of building-out capacitors for the D-66 and H-88 sides have been provided and that the D-66 terminals of the compensator are connected to the D-66 loaded cable and the H-88 compensator terminals to the H-88 cable. Also inspect the connections to determine that no pairs have been split. These checks are in addition to the CBO and gauge considerations discussed in the above paragraphs.

9. EXPECTED MEASURED PERFORMANCE

9.1 Field measurement data have substantiated the structural return loss performance on which the D-66 design has been predicated. Where more than routine care has been taken to design, stake and build the plant this is also reflected in SRL's exceeding the minimum expected values. Where the cable is of one single uniform gauge this also results in higher values of SRL. Lastly, where the cable consists of one gauge and one size (for example, 25 pair, 22 gauge for the entire circuit length) this produces the highest value of SRL possible. This is because in plastic color coded cables like numbered pairs of like gauge and like size tend to have the least amount of mutual capacitance deviation from one reel to another (for the same manufacturer). For this reason with color-to-color splicing of the same numbered pairs in the same binder groups this results in uniform capacitance between each loading section which in turn results in higher than normal values of SRL.

9.2 For cables which are uniform gauge D-66 loaded for their entire length and which meet the load spacing deviations of Section 431, "Voice Frequency Loading For Trunk Cables", paragraphs 3.4 and 3.5 and the cable mutual capacitance deviation requirements in the REA PE Cable specifications, a minimum value of 25 db SFSRL at the critical frequency (CFSRL) and 32 db ESRL minimum are expected.

9.3 For cables which are uniform gauge D-66 loaded for their entire length and where the load spacing is better than the minimum requirements of Section 431, paragraphs 3.4 or 3.5 and/or where a single gauge and single size is used, values of 30 to as much as 35 db CFSRL can be expected as minimum values (worse values) and 42 db ESRL.

9.4 D-66 loaded cables measuring 22 db or less for CFSRL contain significant irregularities and require corrective action. Though for a particular application a value of 22 db CFSRL may be adequate, the outside plant facilities nevertheless do not meet the standards to which they have been engineered.

9.5 Illustrative cases shown in Figs. 20-30 indicate values of SFSRL on D-66 loaded cables which have been measured in REA borrowers' systems and which are considered typical. These examples are illustrative of the performance which can be expected upon measurement for the various conditions discussed in paragraphs 9.1 to 9.3 above.

10. DATA SHEETS FOR RECORDING MEASUREMENTS

10.1 The forms used to record the SFSRL and ESRL measurements and the other information which is required are shown in "Data Sheet - Structural Return Loss Measurements"

10.2 When making the measurements, it is essential that the outside plant facility configuration be accurately known, including the manner by which the measurements have been carried out and any adjustments which have been found necessary. This information is necessary in order to analyze the results and determine whether the objectives are being met or whether corrective action is required. Besides serving as a record for initial acceptance measurements, it also provides the plant forces with a powerful tool for performing routine testing on these circuits or for correcting problems should they occur. It is extremely difficult to evaluate results of transmission measurements, to make recommendations for correction of transmission problems or to perform routine testing when plant and/or test records are lacking or incomplete.

11. ANALYSIS OF RESULTS IN FIGURES 20-35

11.1 (Fig. 20) The worst value of single frequency structural return loss (CFSRL) for this layout is 35.2 db at approximately 2390 cps in the 300-3000 cps band, thereafter called "3000 cycle band" and the echo structural return loss (ESRL) is 41.0 db. The reason for this good performance is due to (a) the load spacing deviation of the as-built plant being 0.3 percent (b) the cable mutual capacitance measured between loading points being very nearly 0.083 microfarads per mile and (c) uniform gauge. Factors (a) and (b) above are the more important ones. Because the consulting engineer for this project was aware of the importance of good loading and implemented this through his resident engineer on the job by exercising extra care in locating the loading points very accurately, the SRL is as good as it can be obtained. Thus, it pays to do a better than routine job whenever this is possible. There is one other important observation in the SRL in this layout. This is that the CFSRL in a 3400 cps band is also very good at 33.5 db. This comes about, again, from the good spacing but also because the capacitance of this pair is uniformly 0.083 mf. Whenever the pair mutual capacitance is uniformly .083 microfarads per mile for the entire cable route of very high SRL values should be expected not only in the 3000 cycle band but even up to 4000 cps. For example, at 4000 cps the SRL of this pair is 31.3 db and this is quite good.

11.02 (Fig. 21) This is a different pair in the same cable and trunk group as the pair shown in Fig. 20. The 3000 cycle band CFSRL is 30.3 db and the ESRL 35.5 db. The SRL for this pair also reflects the care given for obtaining good load spacing. The reason that this pair has a 5 db (approximately) lower CFSRL compared with the pair in Fig. 20 is because the mutual capacitance in this pair is slightly different than 0.083 microfarads per mile. Therefore it has a lesser value of CFSRL. However, this is entirely normal. In a group of pairs (in the same cable sheath and the same trunk group) having unusually high values of SRL the differences in the values between the different pairs will normally be large. This is because the SRL is already so high that even very small deviations become important. It should also be noted that the SRL for this pair stays very good even up to 4000 cps.

11.03 (Fig. 22) The SRL for this pair is very good up to about 2600 cps but it becomes rapidly worse at frequencies higher than this. This is despite the good load spacing in this cable route. The reason for this is that the cable pair in question was measured and found to have a capacitance of approximately 0.087 microfarads per mile (instead of the desired 0.083 value) but this capacitance was uniform for the entire cable route. This makes the return loss at the higher frequencies to be not as good as the lower frequency values. It can also be noted that the ESRL remains very high at 40.5 db. This is because the echo band as discussed in paragraph 4.72 above is between 500 to 2500 cycles and in this frequency region the SRL is very good despite the higher than normal capacitance of this cable pair. The CFSRL is 30.2 db up to 3000 cps. This meets the objective and is actually better than the objective. Thus, with the D-66 loading system, if the load spacing is good, even pairs with higher mutual capacitance than that desired can still give good values of structural return loss in a 3000 cps band if the cable capacitance remains uniformly high for the entire cable route.

11.04 (Fig. 23) In this figure the SRL of the same pair shown in Fig. 22 is shown but measured from the opposite office. It is now seen by comparing Figs. 22 and 23 that the SRL values are not the same. They should not be expected to be the same. The irregularities in a loaded cable will normally be different when viewed from the opposite circuit ends. The values of their CFSRL, however, should be comparable. In the 3000 cycle band the difference is 3.2 db (33.4 -30.2 db) and this is considered normal. This figure also shows the effect of building out capacitance. For example, by placing the 0.009 microfarad capacitor to build out the 3912 foot section, the SRL is improved considerably above 2200 cps. This improvement is 6 db at 2500

cps and 2.3 db at 3000 cps. Therefore, if capacitance building out is not used where needed the resulting SRL will be lower than that which can be realized.

11.05 (Figs. 24-25) The same pair is measured in these figures but from opposite directions. It is seen that the waveshape is not the same, again, because the irregularity is not the same in each direction of transmission. However, the critical values are close enough so that they can be considered to be within the normal range of variation. In Fig. 24 the CFSRL is 30.3 db, whereas in Fig. 25 it is 31.0 db. However, whereas in Fig. 24 the CFSRL is at about 2660 cps, in Fig. 25 it is at 3100 cps and this is also considered normal. The CFSRL values meet the objectives when measured from each office.

11.06 (Fig. 26) The SRL is very high up to about 2600 cps but this pattern is not maintained for frequenc[ies] higher than this. This is despite the good load spacing, the uniform gauge and the uniform size of the cable. This can be explained by the 0.088 microfarad per mile mutual capacitance for this pair for the entire route which is higher than the desired value of .083. However, because the D-66 loading has a wide band, this affect does not begin to show until frequencies of 3000 cps or higher. Thus, very good SRL value[s] are obtained in this band despite the high capacitance of the cable pair. The 3000 cycle band CFSRL is 29.5 db and this is considered quite good.

11.07 (Figs. 27-28) In Figs. 27 and 28 it is shown what can be expected as the worst values of CFSRL with D-66 loading when the pair capacitance is higher than the desired .083 microfarads per mile, but is uniformly high at this value for the entire route and when the load spacing is also good. It can be seen th[at] the respective CFSRL values are 26.8 and 27.3 db and these are about the worst values which should be expect[ed]. The ESRL values are 36.0 and 38.0 db and these values should be considered typical for D-66 loading under th[e] conditions indicated.

11.08 (Figs. 29-30) These are illustrative of what can be expected with mixed gauges. The CFSRL values are much lower than the values in the previous figures for uniform gauge. For example, the respective CFSRL values are 25.5 and 25.6 db. The critical frequency is now at the low end of the band at 300 cps. Because the precision balancing net is set for one particular gauge only it is not possible to match the many gauges in the outside plant. What therefore results is a compromise value of SRL. The higher frequency SRL, starting at frequencies higher than 2000 cps, is not affected by the mixture of gauges. Mixing the different gauges affects frequencies lower than 1000 cycles and especially around 300 cps. The reason that the high frequency SRL is not as good is because of the different values of capacitance in the loading sections. For the pairs shown some sections measured were found to have a mutual capacitance lower than the desired value of .083 microfarads per mile while others had higher capacitance than this. Thus, the mutual capacitance value is not uniform throughout the cable route. For this reason the high frequency CFSRL for these pairs is not nearly as good as for the pairs in the previous figures. There the capacitance was highe[r] than .083 microfarads per mile but this value was uniformly the same for the entire cable route.

11.09 (Fig. 31) This H-88 loaded pair is typical of what can be expected in an H-88 loaded system which has (a) close to ideal end-sections (b) reference spacing deviation better than .5 percent (c) unifo[rm] gauge (d) RMS cable capacitance deviation of 1.7 percent and (e) random splicing. The CFSRL is 22.5 db at 1600 cps in a 3000 cps band. It should be noted that the SRL of the cable becomes extremely poor at frequen[c]ies higher than 3000 cps but this is typical of H-88 loading.

11.10 (Fig. 32) This figure is representative of H-88 loading having (a) mixed gauges and (b) one long full section (6229 feet). The CFSRL value is 18.3 db. This is 7.3 db worse than the example in Fig. 29 which also has mixed gauges and also large variation in capacitance but which is D-66 loaded.

11.11 (Fig. 33) In this layout the loading points have been spaced with extreme precision so that the loa[d] spacing deviation is close to zero and the gauge is uniform. Therefore, the SRL in this layout is representative of what should be expected of an "ideally spaced" H-88 loaded system. The CFSRL is 25.6 db at 2990 cps in a 3000 cycle band which is exceptionally good. It should be noted that the SRL drops rapidly at frequencies higher than 3000 cps and this is to be expected because this is a basic characteristic of thi[s] loading system.

11.12 (Fig. 34) This layout is representative of what can be expected in a D-66/H-88 loaded system joined with the D-66/H-88 junction impedance compensator. The CFSRL is 23.0 db. This is not as high as the D-66 examples shown in the previous figures. The reason for this lower value is because it connects with the H-88 loading system and the H-88 becomes the controlling factor. For such compensated layouts the 23 db CFSR[L]

le.

are shown in this figure measured with the Siemens- ske Level

d H-88 loaded cables. The curves are read as foll : At any

cal axis are read. To this the received level value is added

rth layout the SFSRL value at 2000 cps is:

Vertical Axis:	- 5 db
Receive :	-20 db
Algebraic Sum:	-25 db

Therefore the SRL at this frequency is 25 db.

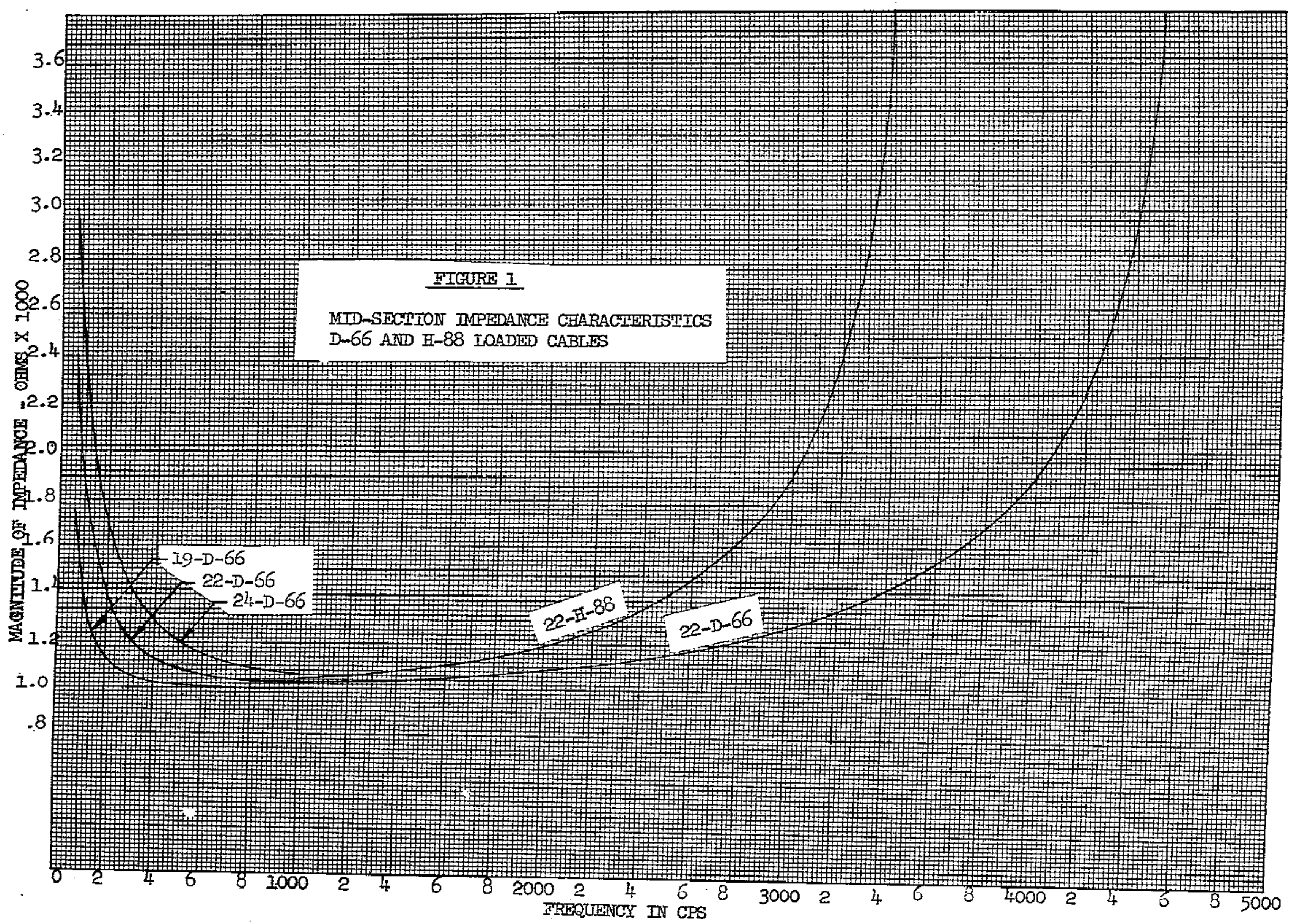


FIGURE 1
MID-SECTION IMPEDANCE CHARACTERISTICS
D-66 AND H-88 LOADED CABLES
19-D-66
22-D-66
24-D-66
22-H-88
22-D-66
MAGNITUDE OF IMPEDANCE, OHMS X 1000
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
0
2
4
6
8
1000
2
4
6
8
2000
2
4
6
8
3000
2
4
6
8
4000
2
4
6
8
5000
FREQUENCY IN CPS

FIGURE 2
VARIATION OF IMPEDANCE WITH
FREQUENCY AND END SECTION LENGTH
FOR 24 AND 22-D-66 CABLES

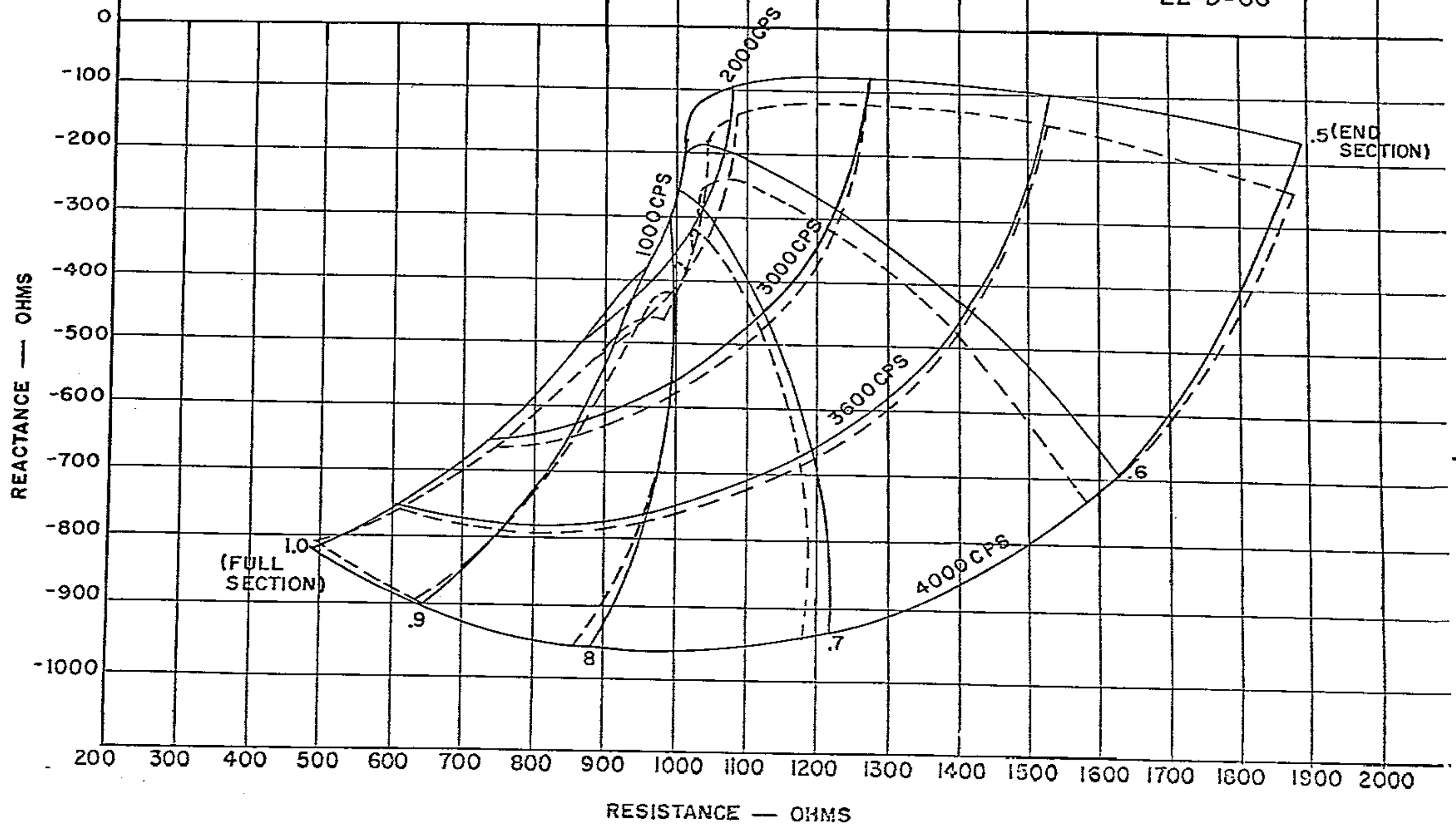
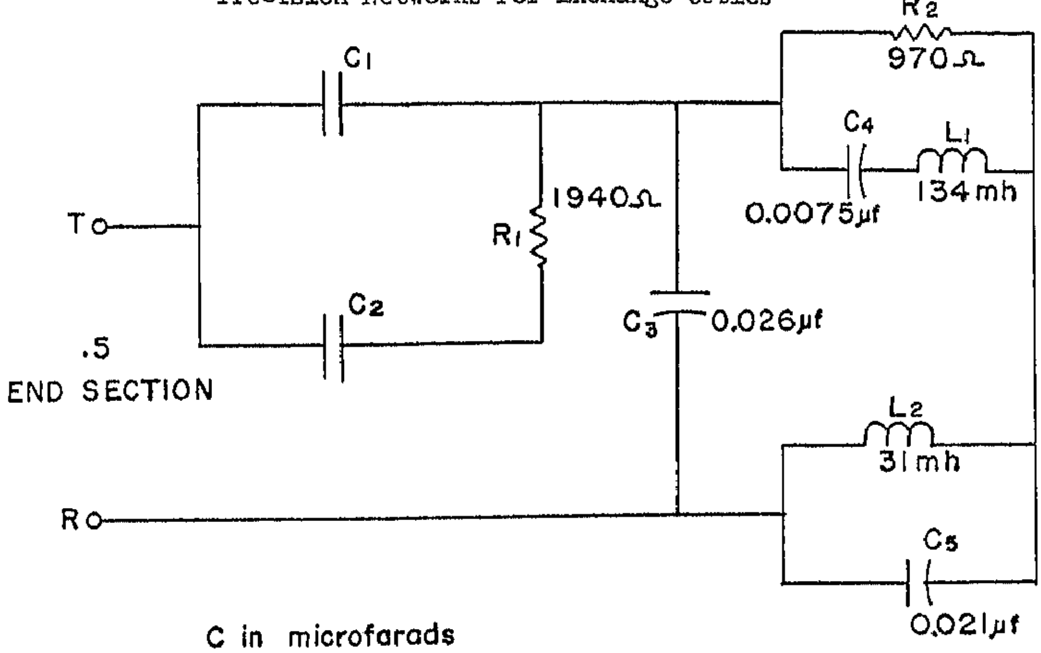


FIGURE 3

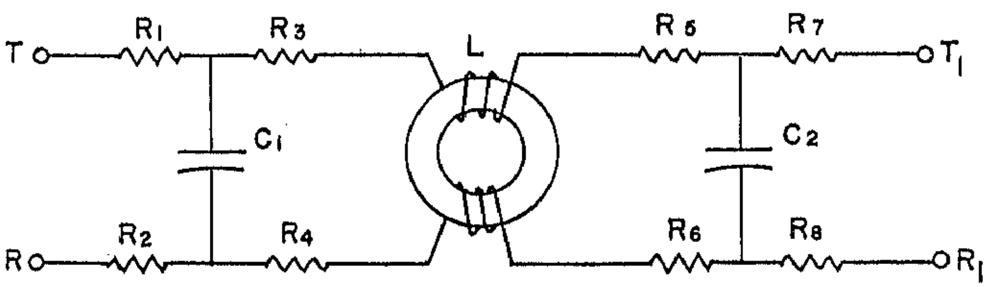
Configuration for 19, 22, and 24 Gauge D-66
Precision Networks For Exchange Cables



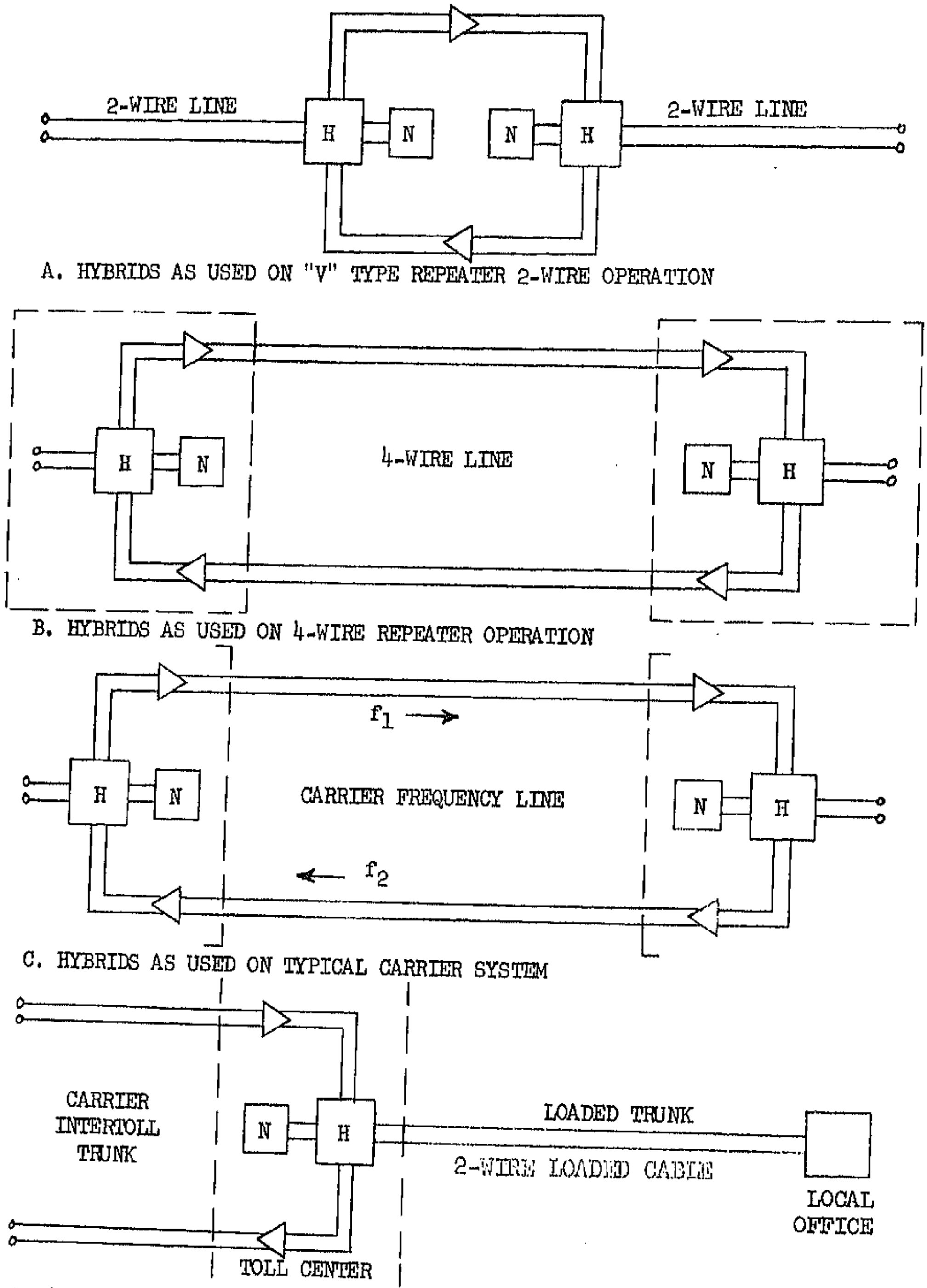
C in microfarads

19 GAUGE	22 GAUGE	24 GAUGE
C_1 = 1.686	C_1 = 0.936	C_1 = 0.585
C_2 = 2.310	C_2 = 1.070	C_2 = 0.715

Configuration for 19, 22, and 24 Gauge
D-66 Artificial Loaded Lines



	19 GAUGE	22 GAUGE	24 GAUGE
R_{1-8}	9.05Ω	18.2Ω	29.2Ω
L	66mh	66mh	66mh
$C_{1,2}$	0.03535μf	0.03535μf	0.03535μf



A. HYBRIDS AS USED ON "V" TYPE REPEATER 2-WIRE OPERATION

B. HYBRIDS AS USED ON 4-WIRE REPEATER OPERATION

C. HYBRIDS AS USED ON TYPICAL CARRIER SYSTEM

D. 4-WIRE TERMINATING SET AS USED AT TOLL CENTER TO CONNECT INTERTOLL TO TOLL CONNECTING TRUNK

FIGURE 5 TYPICAL APPLICATIONS WHERE HYBRIDS ARE USED

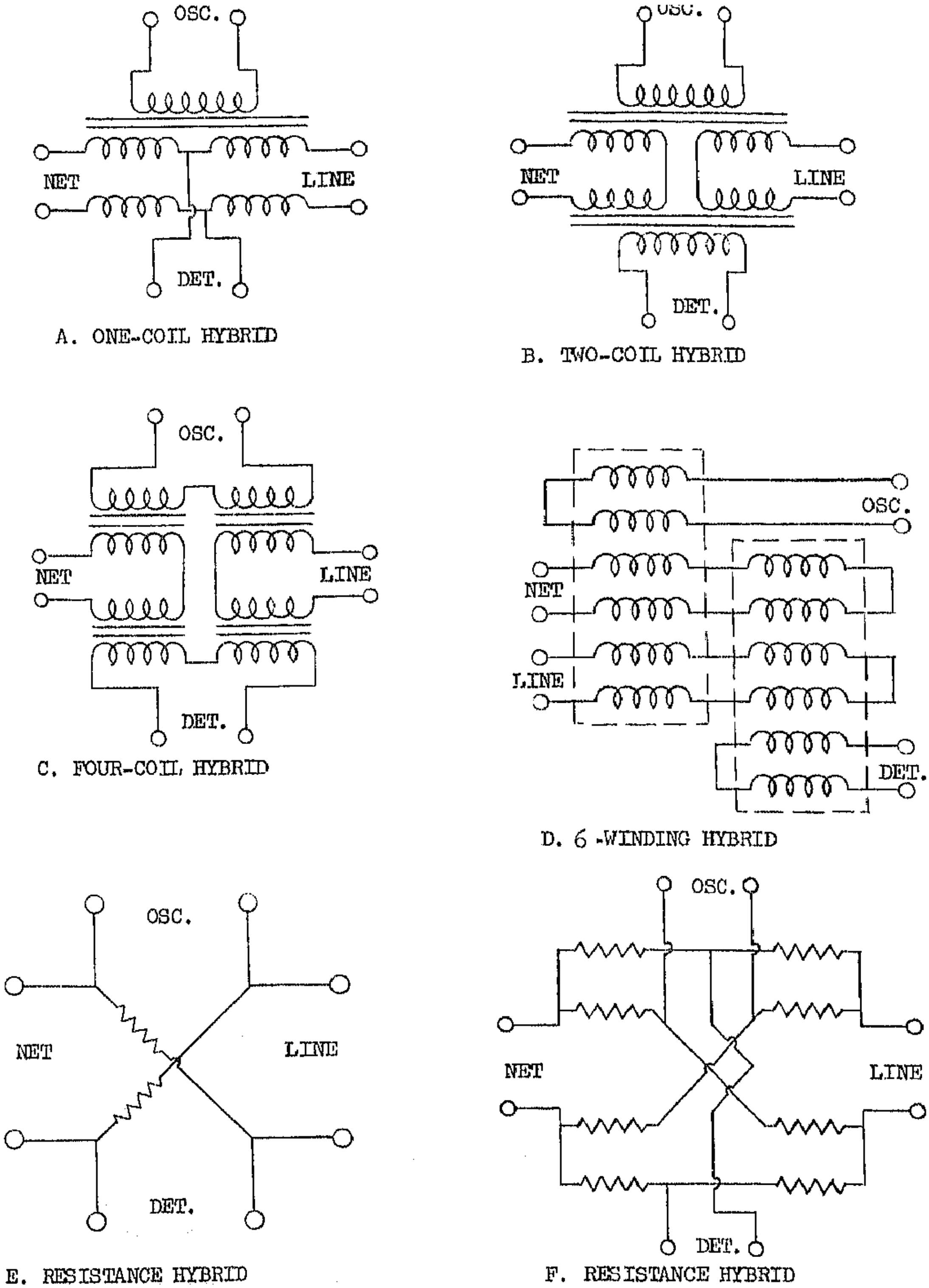
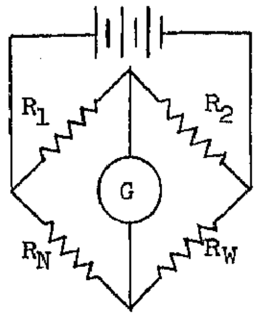
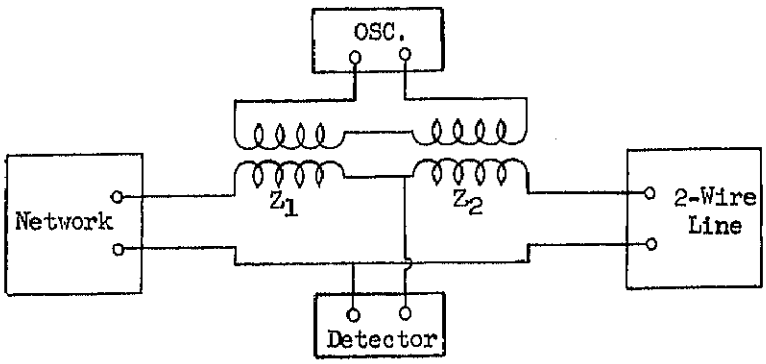


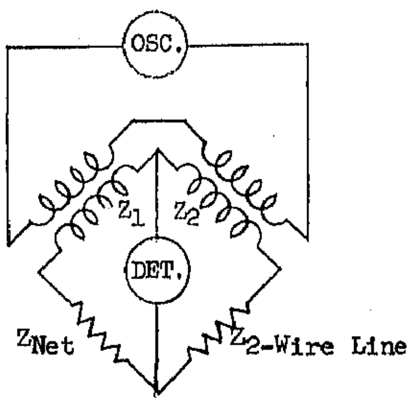
FIGURE 6 VARIOUS TYPES OF COIL AND RESISTANCE HYBRIDS



A. Conventional D.C. Wheatstone Bridge Circuit



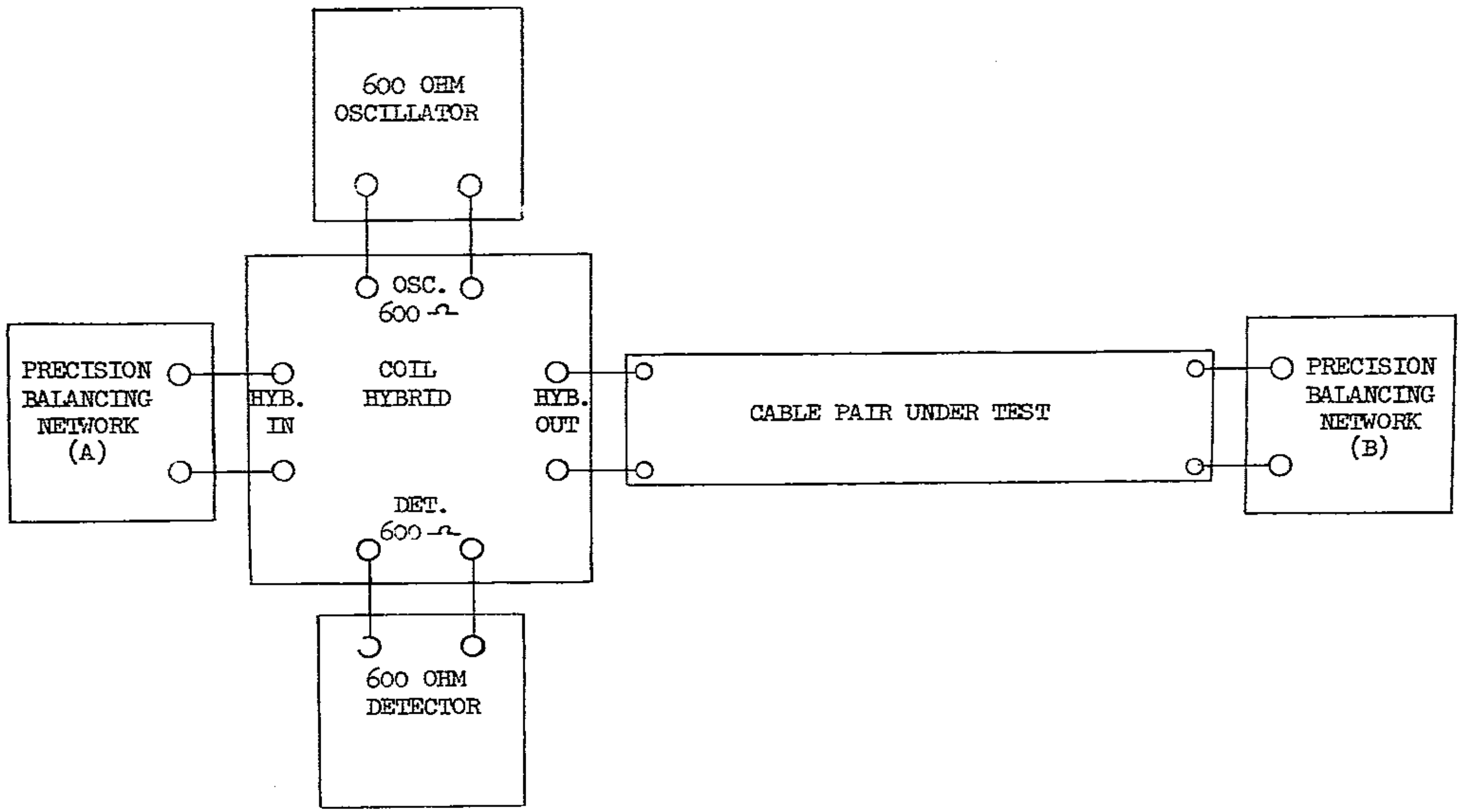
B. Simplified Coil Type Hybrid



C. Coil Hybrid of (B) above redrawn on a Wheatstone Bridge Basis

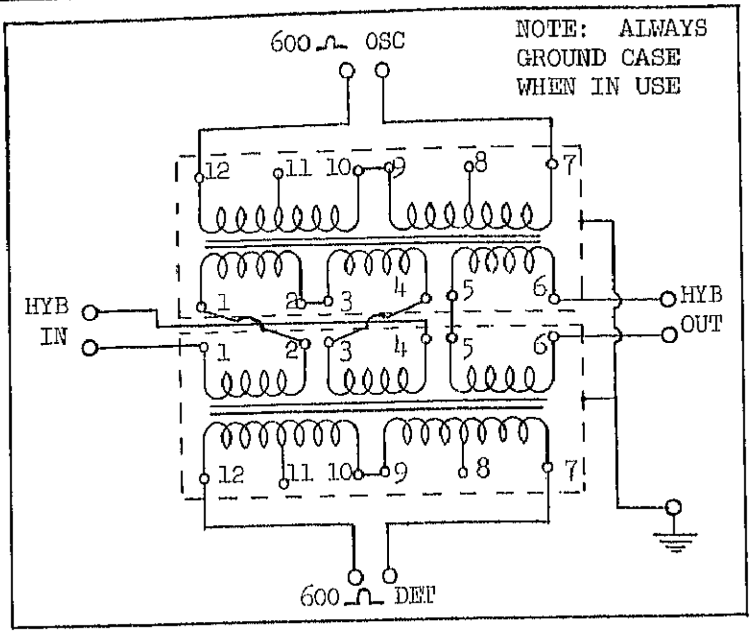
THE HYBRID AS AN ANALOGY TO THE WHEATSTONE BRIDGE

FIGURE 7

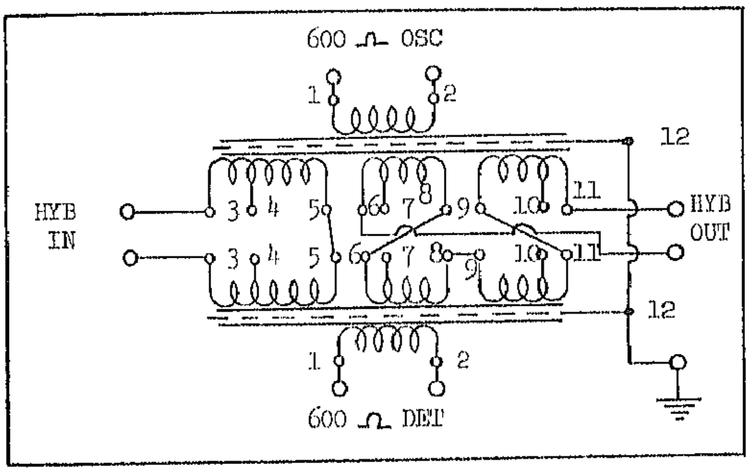


BASIC DIAGRAM FOR THE SRL MEASUREMENT

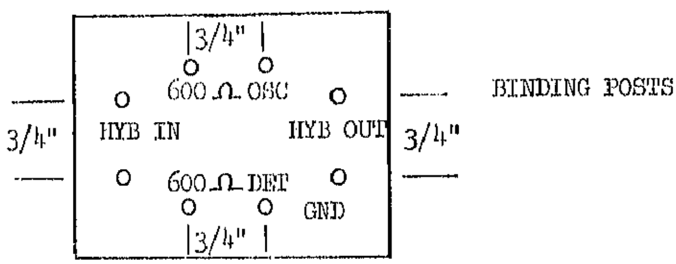
FIGURE 8



WIRING DIAGRAM OF TWO W.E. CO. 120P REPEATING COILS USED TO FORM A HYBRID



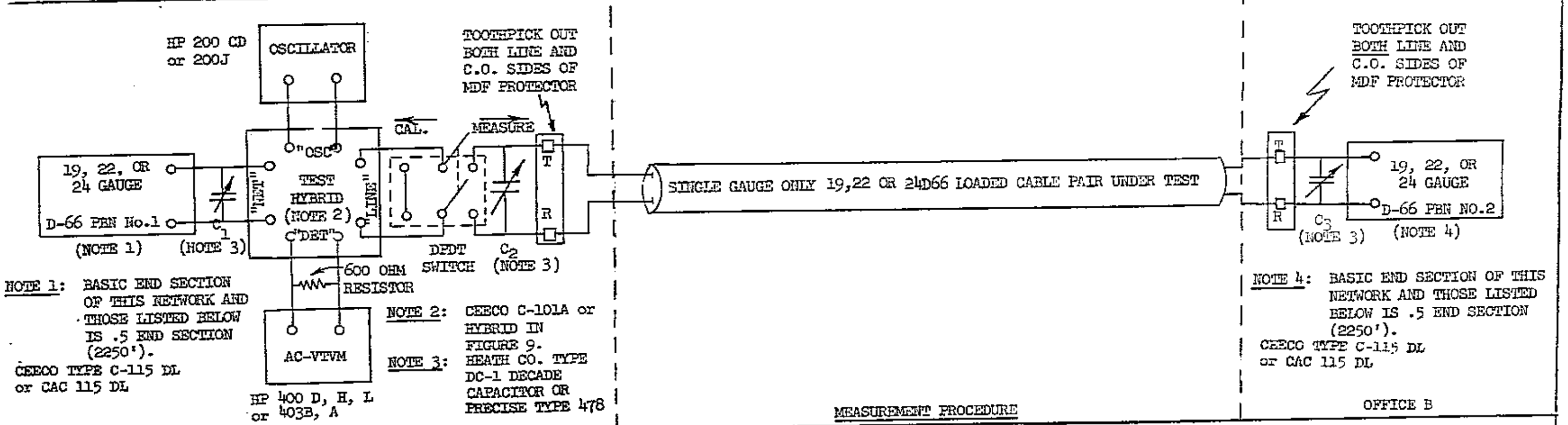
WIRING DIAGRAM OF TWO ALTEC LANSING 15189 REPEATING COILS USED TO FORM A HYBRID



SUGGESTED PHYSICAL LAYOUT OF HYBRID FACEPLATE

WIRING DIAGRAMS FOR THE CONSTRUCTION OF TEST COIL HYBRIDS

FIGURE 9



MEASUREMENT PROCEDURE

DO NOT ATTEMPT MEASUREMENTS BEFORE READING ENTIRE PARAGRAPH 8

1. Connect the test equipment and cable pair under test as shown above. Be sure to strap or set PBN "gauge terminals" for same gauge as gauge of cable being measured.

2. Throw DPDT switch to "CALIBRATE" position. Set oscillator frequency to 2000 cps and vary output level until A.C.-VTVM reads 0 dbm (zero dbm); this completes calibration. Throw DPDT switch to "MEASURE" position. Do not change oscillator output level control. Set C_2 to build-out cable end section to 2250' total.

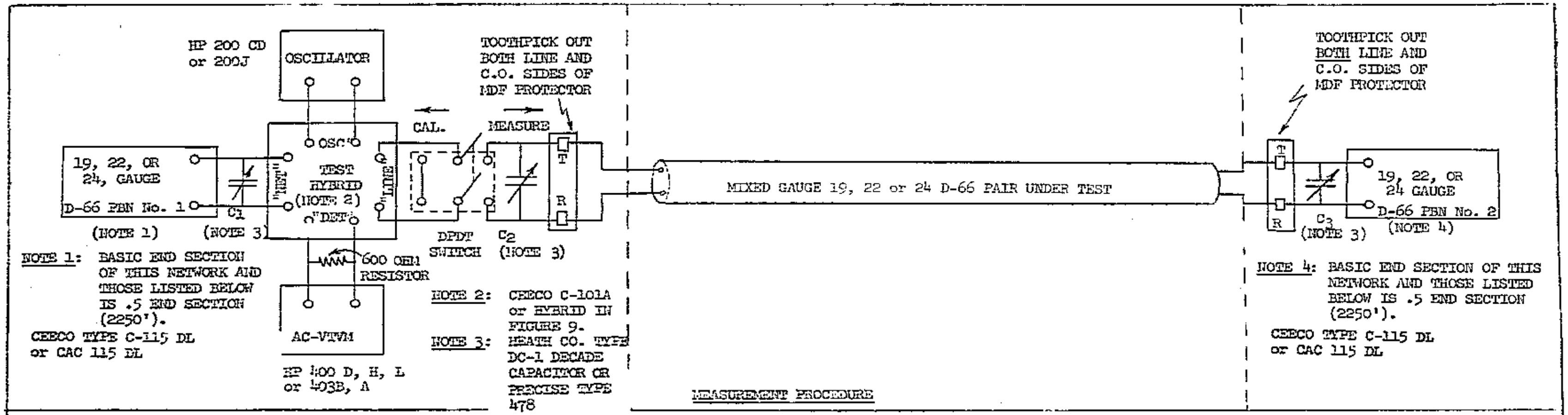
3. Vary oscillator frequency vernier, slowly, between 200 to 4500 cps and note the frequencies which give consecutive maximum (peak) and minimum (valley) readings on the A.C.-VTVM. Read each peak and valley frequency and the minus dbm reading on the A.C.-VTVM corresponding to each and enter the results in the "Data Sheets—Structural Return Loss Measurements."

4. Increase value of C_2 from that in step (2) and repeat step (3). Note whether SRL becomes better or worse particularly between 2500 to 3000 cps (SRL becomes better as readings in A.C.-VTVM get more negative.) If SRL gets better this means that end section is electrically less than 2250 feet (though by length alone it is 2250 feet). Vary C_2 until the value is found that gives the best SRL (especially between 2500 to 3000 cps).

5. If by increasing C_2 in step (4), SRL gets worse, this means that the cable end section is longer than 2250 feet electrically. Return C_2 to its original value in step (2) (to give 2250 feet end-section total). Increase C_1 until the best possible SRL is obtained (especially between 2500 to 3000 cps). Record the results in the "Data Sheet—SINGLE FREQUENCY STRUCTURAL RETURN LOSS (SFSRL) FOR D-66 LOADING. Record also the SRL value at 3400 cps.

6. If by increasing C_1 or C_2 SRL gets worse, this means that the end section as built out in step (2) to 2250 feet is not only 2250 feet in length but also 2250 feet electrically, which is the important thing. If this is the case, continue with the measurement as per item (3) and record the data in the "Data Sheet—Structural Return Loss Measurements."

FIGURE 10. SINGLE FREQUENCY STRUCTURAL RETURN LOSS MEASUREMENT OF ONE UNIFORM GAUGE ONLY FOR ENTIRE CIRCUIT LENGTH (19, 22 OR 24-D-66)



DO NOT ATTEMPT MEASUREMENTS BEFORE READING ENTIRE PARAGRAPH 8

1. Connect the test equipment and cable pair under test as shown above. Set gauge of PBN No. 1 for most predominant gauge adjacent to hybrid and PBN No. 2 for most predominant gauge adjacent to it.

2. Throw DPDT switch to "CALIBRATE" position. Set oscillator frequency to 2000 cps and vary output level control until A.C.-VTVM reads 0 dbm (zero dbm); this completes calibration. Do not change oscillator output level control. Throw DPDT switch to "MEASURE" position. Set C_2 to build-out cable end section to 2250' total.

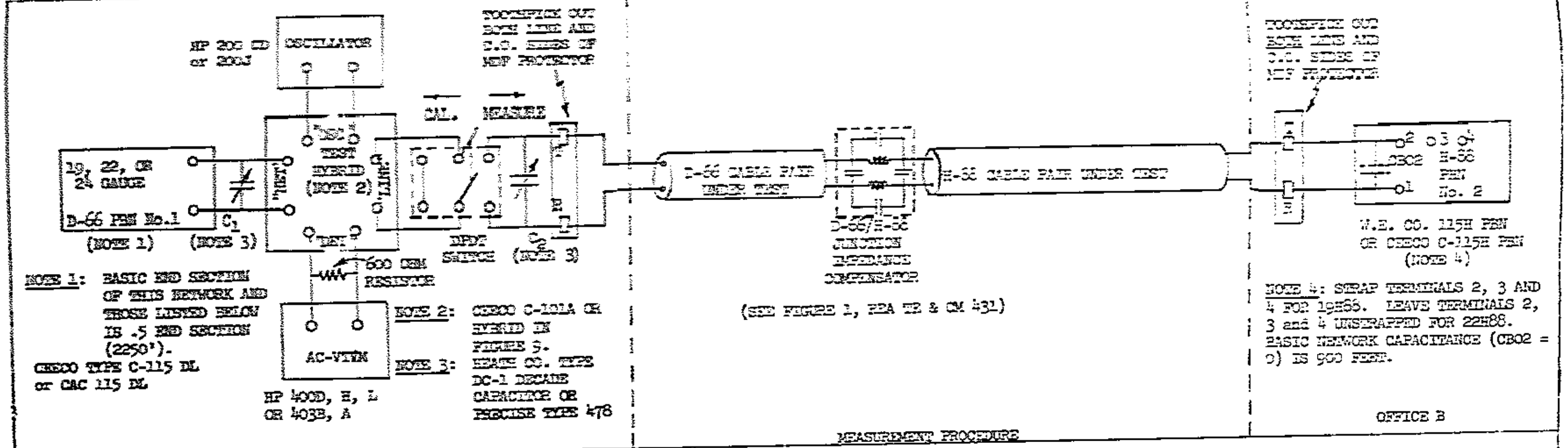
3. Vary oscillator frequency vernier, slowly, between 200 to 4500 cps and note the frequencies which give consecutive maximum (peak) and minimum (valley) readings on the A.C.-VTVM. Read each peak and valley frequency and the minus dbm reading on the A.C.-VTVM corresponding to each. Change gauge of PBN No. 1 (if it is set for 19 gauge in step (1), change it to 22 or 24) and note if this improves the SRL. If it does, leave set for new gauge setting; if not, change back to original gauge. Change gauge of PBN No. 2 from that in step (1) and note if this improves SRL. If it does, leave set for new gauge setting; if not, change back to original gauge. (VARYING GAUGE OF PBN NOS. 1 AND 2 ALTERNATELY WILL BE NECESSARY, DEPENDING ON ACTUAL CABLE LAYOUT, TO OBTAIN BEST SRL.) Record best SRL in the "Data Sheet--Structural Return Loss Measurements."

4. Increase value of C_2 from that in step (2) and repeat step (3). Note whether SRL becomes better or worse particularly between 2500 to 3000 cps (SRL becomes better as readings in A.C.-VTVM get more negative.) If SRL gets better this means that end section is electrically less than 2250 feet (though by length along it is 2250 feet). Vary C_2 until the value is found that gives the best SRL (especially between 2500 to 3000 cps).

5. If by increasing C_2 in step (4), SRL gets worse, this means that the cable end section is longer than 2250 feet electrically. Return C_2 to its original value in step (2) (to give 2250 feet end-section total). Increase C_1 until the best possible SRL is obtained (especially between 2500 to 3000 cps). Record the results in the "Data Sheet--SINGLE FREQUENCY STRUCTURAL RETURN LOSS (SFSRL) FOR D-66 LOADING. Record also the SRL value at 3400 cps.

6. If by increasing C_1 or C_2 SRL gets worse, this means that the end section as built out in step (2) to 2250 feet is not only 2250 feet in length but also 2250 feet electrically; which is the important thing. If this is the case, continue with the measurement as per item (3) and record the data in the "Data Sheet--Structural Return Loss Measurements."

FIGURE 11. SINGLE FREQUENCY STRUCTURAL RETURN LOSS MEASUREMENT OF D-66 LOADED CABLES WITH MIXED 19, 22 or 24 GAUGES



DO NOT ATTEMPT MEASUREMENTS BEFORE READING ENTIRE PARAGRAPH 8

Measuring at the D-66 end

1. If gauge is uniform, that is, all 19-gauge or all 22-gauge for both the D-66 and H-88, use the measurement procedure of Figure 10.

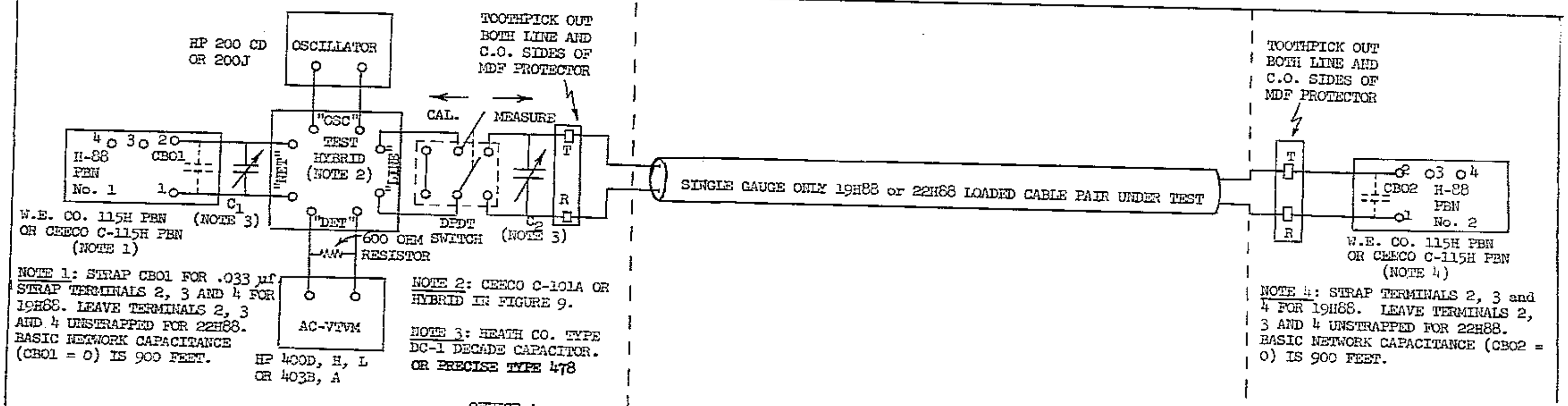
2. If gauges are mixed, used measurement procedure of Figure 11.

Measuring at the H-88 end

3. If gauge is uniform, that is, all 19-gauge or all 22-gauge for both the D-66 and H-88, use the measurement procedure of Figure 13.

4. If gauges are mixed, use measurement procedure of Figure 14.

FIGURE 12. SINGLE FREQUENCY STRUCTURAL RETURN LOSS MEASUREMENT OF D-66/H-88 LOADED CABLES USING THE D-66/H-88 JUNCTION IMPEDANCE COMPENSATOR



MEASUREMENT PROCEDURE

DO NOT ATTEMPT MEASUREMENTS BEFORE READING ENTIRE PARAGRAPH 8

1. Connect the test equipment and cable pair under test as shown above. Be sure to short terminals 2, 3, and 4 in PBN's Nos. 1 and 2 for 19 gauge and leave unstrapped for 22 gauge.

2. Set CBO1 in PBN No. 1 to .033 µf. Set CBO2 to build out PBN No. 2 to same value as physical length of cable end section. (Remember! 900 feet of this is already in the basic net of the PBN.) Set C_2 to build-out cable end section to 3000' total.

3. Throw DPDT switch to "CALIBRATE" position. Set oscillator frequency to 2000 cps and vary output level until AC VTVM reads 0 dbm (Zero dbm); this completes calibration. Throw DPDT switch to "MEASURE" position. Do not change oscillator output level control.

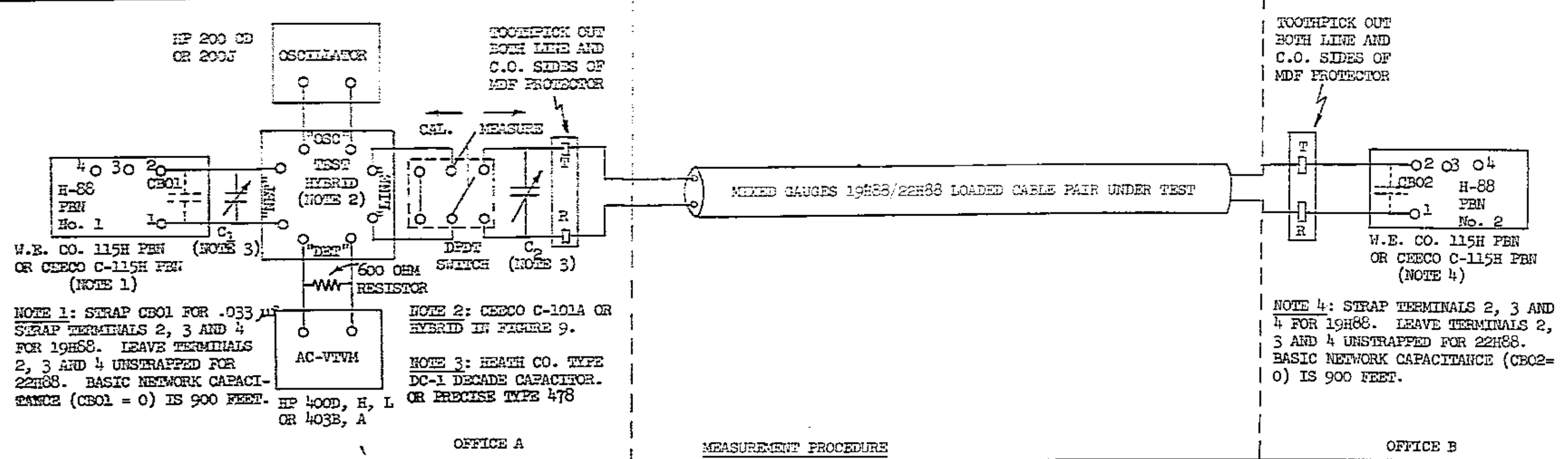
4. Vary oscillator frequency vernier, slowly, between 200 to 3400 cps and note the frequencies which give consecutive maximum (peak) and minimum (valley) readings on the AC VTVM. Read each peak and valley frequency and the minus dbm reading on the AC VTVM corresponding to each and enter the results on the "Data Sheet - Structural Return Loss Measurements."

5. Increase value of C_2 from that in step (2) and repeat step (4). Note whether SRL becomes better or worse particularly between 2500 to 3000 cps. (SRL becomes better as readings in AC VTVM get more negative.) If SRL gets better this means that end section is electrically less than 3000 feet (though by length alone it is 3000 feet). Vary C_2 until the value is found that gives the best SRL (especially between 2500 to 3000 cps).

6. Increase C_2 in step (5). If SRL gets worse, this means that the cable end section is longer than 3000 feet electrically. Return C_2 to its original value in step (2) (to give 3000 feet end-section total). Increase C_1 until the best possible SRL is obtained (especially between 2500 to 3000 cps). Record the results in the "Data Sheet - Structural Return Loss Measurements."

7. If by increasing C_1 or C_2 SRL gets worse, this means that the end section as built out in step (2) to 3000 feet is not only 3000 feet in length but also 3000 feet electrically, which is the important thing. If this is the case, continue with the measurement as per item (4) and record the data in the "Data Sheet - Structural Return Loss Measurements."

FIGURE 1[illegible]. SINGLE FREQUENCY STRUCTURAL RETURN LOSS MEASUREMENT OF ONE UNIFORM GAUGE ONLY FOR ENTIRE CIRCUIT LENGTH (19H88 or 22H88)



DO NOT ATTEMPT MEASUREMENTS BEFORE READING ENTIRE PARAGRAPH 8

1. Connect the test equipment and cable pair as shown above. Set gauge of PBN No. 1 for most predominant gauge adjacent to hybrid and PBN No. 2 for most predominant gauge adjacent to it.

2. Set CB01 in PBN No. 1 to .033 µf. Set CB02 to build out PBN No. 2 to same value as physical length of cable end section. (Remember! 900 feet is already in the basic net of the PBN.) Set C_2 to build-out cable end section to 3000' total.

3. Throw DPDT switch to "CALIBRATE" position. Set oscillator frequency to 2000 cps and vary output level control until AC-VTVM reads 0 dbm (zero dbm); this completes calibration. <u>Do not change oscillator output level control</u>. Throw DPDT switch to "MEASURE" position.

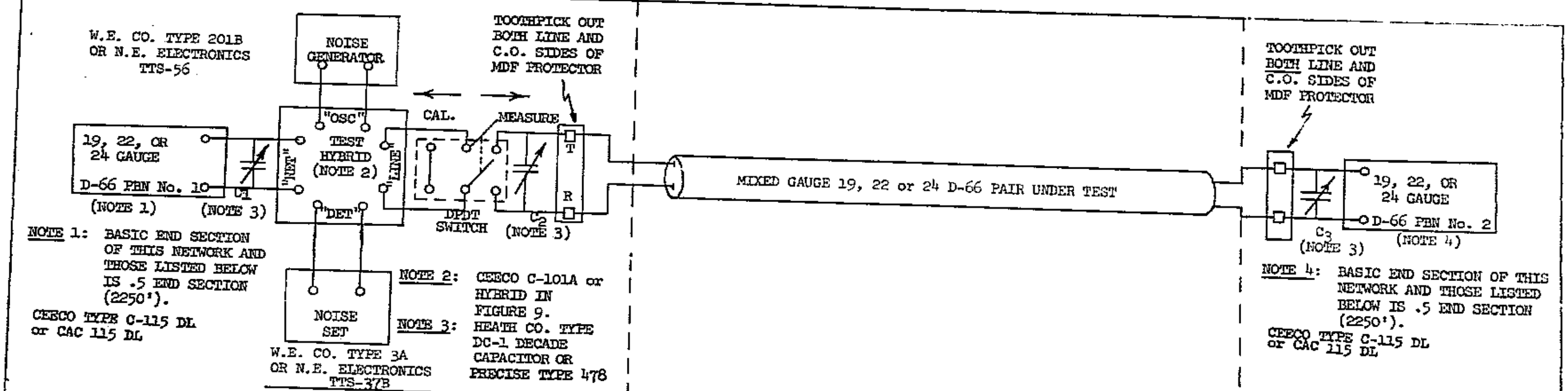
4. Vary oscillator frequency vernier, slowly, between 200 to 3400 cps and note the frequencies which give consecutive maximum (peak) and minimum (valley) readings on the AC -VTVM. Read each peak and valley frequency and the minus dbm reading on the AC -VTVM corresponding to each. Change gauge of PBN No. 1 (if it is set for 19 gauge in step (1), change it to 22 gauge) and note if this improves the SRL. If it does, leave set for new gauge setting; if not, change back to original gauge. Change gauge of PBN No. 2 from that in step (1) and note if this improves SRL. If it does, leave set for new gauge setting; if not, change back to original gauge. (VARYING GAUGE OF PBN NOS. 1 <u>AND</u> 2 ALTERNATELY WILL BE NECESSARY, DEPENDING ON ACTUAL CABLE LAYOUT, TO OBTAIN BEST SRL.) Record <u>best</u> SRL in the "Data Sheet-Structural Return Loss Measurements."

5. Increase value of C_2 from that in step (2) and repeat step (4). Note whether SRL becomes better or worse particularly between 2500 to 3000 cps (SRL becomes better as readings in AC -VTVM get more negative.) If SRL gets better this means that end section is electrically less than 3000 feet (though by length alone it is 3000 feet). Vary C_2 until the value is found that gives the <u>best</u> SRL (especially between 2500 to 3000 cps).

6. If by increasing C_2 in step (5), SRL gets worse, this means that the cable end section is <u>longer</u> than 3000 feet electrically. Return C_2 to its original value in step (2) (to give 3000 feet end-section total). Increase C_1 until the best possible SRL is obtained (especially between 2500 to 3000 cps). Record the results in the "Data Sheet-Structural Return Loss Measurements."

7. If by increasing C_1 or C_2 SRL gets worse, this means that the end section as built out in step (2) to 3000 feet is not only 3000 feet in length but also 3000 feet <u>electrically</u>, which is the important thing. If this is the case, continue with the measurement as per item (4) and record the data in the "Data Sheet-Structural Return Loss Measurements."

FIGURE 14. SINGLE FREQUENCY STRUCTURAL RETURN LOSS MEASUREMENT OF H-88 LOADED CABLES WITH MIXED 22 and 19 GAUGES



MEASUREMENT PROCEDURE

DO NOT ATTEMPT MEASUREMENTS BEFORE READING ENTIRE PARAGRAPH 8

1. Calibrate the 3A NMS by itself and the 201B by itself before proceeding with the measurement according to Calibration instructions.

2. Connect the test equipment and cable pair under test as shown above. Set C_2 to build-out cable end section to 3000' total. Be sure to strap or set PBN "gauge terminals" for same gauge as gauge of cable being measured.

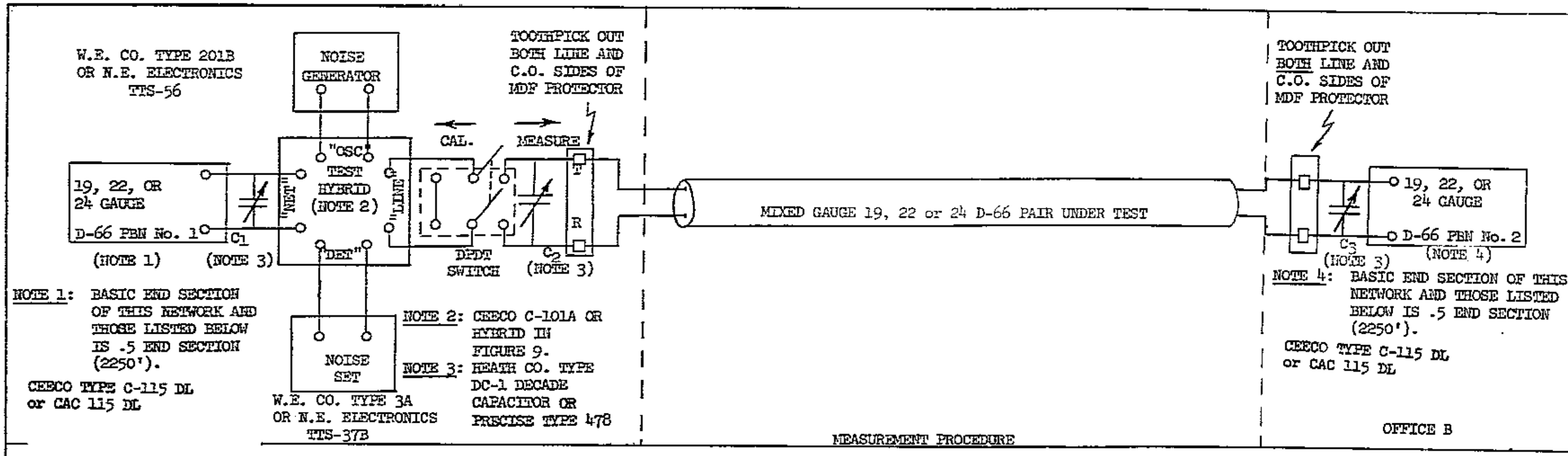
3. Throw DPDT switch to "CALIBRATE" position. Set "OUTPUT ATTEN." pad of 201B noise generator to the 8 db position and note the reading on the 3A NMS. 3A should read 89 dbrn-C. (Function switch of 3A must be in "NM 600" position and "C-Message Network" must be plugged in.) If 3A reads slightly higher or lower than this adjust "OUTPUT ATTEN." pad of 201B until the 89 dbrn-C is obtained on the 3A NMS. This completes calibration. Throw DPDT switch to "MEASURE" position. Do not change 201B output level control.

4. Read dbrn-C reading in 3A NMS. Vary C_2 and/or C_1 until lowest (best) reading is obtained in 3A NMS. This is the best reading and it is the one which should be recorded. Also, vary the C_3 at the far end. See if reading on 3A gets lower (better). If it does record this reading. If not, record the best reading (varying C_3 will normally have no effect on the 3A NMS if the circuit has a loss of 5 db or greater).

5. The echo structural return loss (ESRL) in db is the difference between: [ESRL = 89 - dbrn-C reading, step (5)] in db.

6. Record the data in DATA SHEET - ECHO STRUCTURAL RETURN LOSS (ESRL) FOR D-66 LOADING.

FIGURE 15. ECHO STRUCTURAL RETURN LOSS MEASUREMENT (ESRL) OF ONE UNIFORM GAUGE ONLY FOR ENTIRE CIRCUIT LENGTH (19-D-66 ONLY OR 22-D-66 ONLY OR 24-D-66 ONLY)



DO NOT ATTEMPT MEASUREMENTS BEFORE READING ENTIRE PARAGRAPH 8

1. Calibrate the 3A NMS by itself and the 201B by itself before proceeding with the measurement according to Calibration instructions.

2. Connect the test equipment and cable pair under test as shown above. Be sure to strap or set PBN "gauge terminals" for same gauge as the predominant cable gauge being measured. Set C_2 to build-out cable end section to 2250' total.

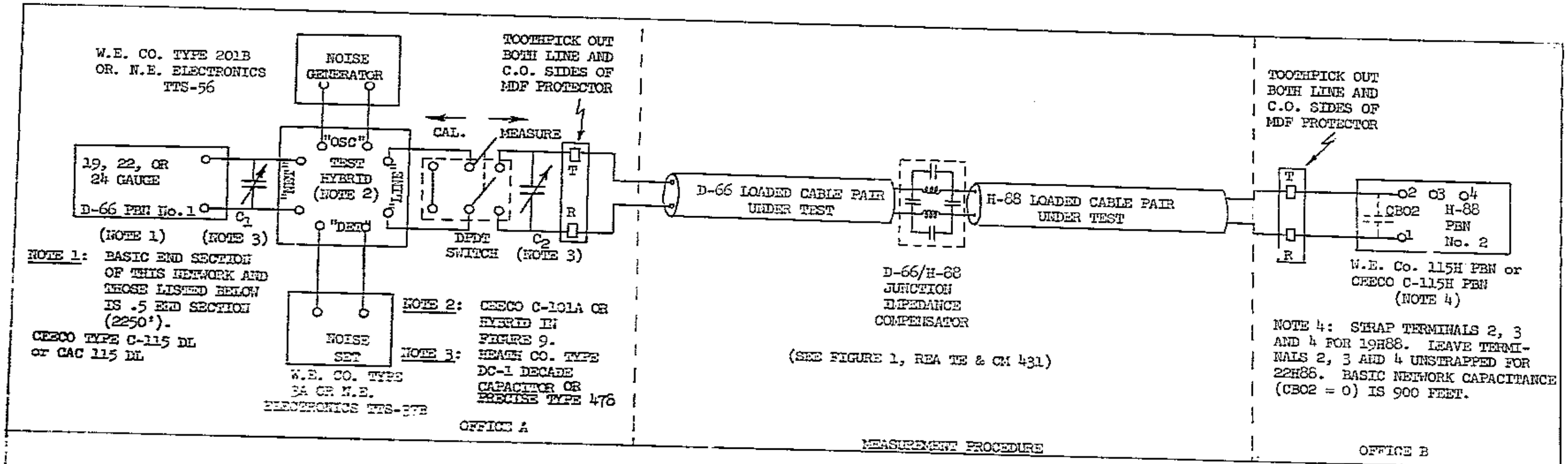
3. Throw DPDT switch to "CALIBRATE" position. Set "OUTPUT ATTEN." pad of 201B noise generator to the 8 db position and note the reading on the 3A NMS. The 3A should read 89 dbrn-C. (Function switch of 3A NMS must be on "NM 600" position and "C-Message Network" must be plugged in.) If 3A reads slightly higher or lower than this, adjust "OUTPUT ATTEN." pad of 201B until the 89 dbrn-C is obtained on the 3A. This completes calibration. Throw DPDT switch to "MEASURE" position. Do not change 201B output level pad.

4. Read dbrn-C reading in 3A NMS. Vary C_2 or C_1 until lowest (best) reading is obtained on 3A. Next, vary the gauge of PBN No. 1 and PBN No. 2 until the reading on 3A becomes the lowest possible. (This procedure involves varying C_1, C_2, gauge of PBN No. 1 and No. 2 until the combination is found which produces the lowest reading on the 3A NMS.) The lowest reading on the 3A is the reading to record.

5. The echo structural return loss (ESRL) in db is: $\boxed{\text{ESRL} = 89 - \text{dbrn-C reading, step (5)}}$ in db.

6. Record the data in DATA SHEET - ECHO STRUCTURAL RETURN LOSS (ESRL) FOR D-66 LOADING.

FIGURE 16. ECHO STRUCTURAL RETURN LOSS (ESRL) MEASUREMENT OF D-66 LOADED CABLES WITH MIXED 19, 22 and 24 GAUGES



DO NOT ATTEMPT MEASUREMENTS BEFORE READING ENTIRE PARAGRAPH 8

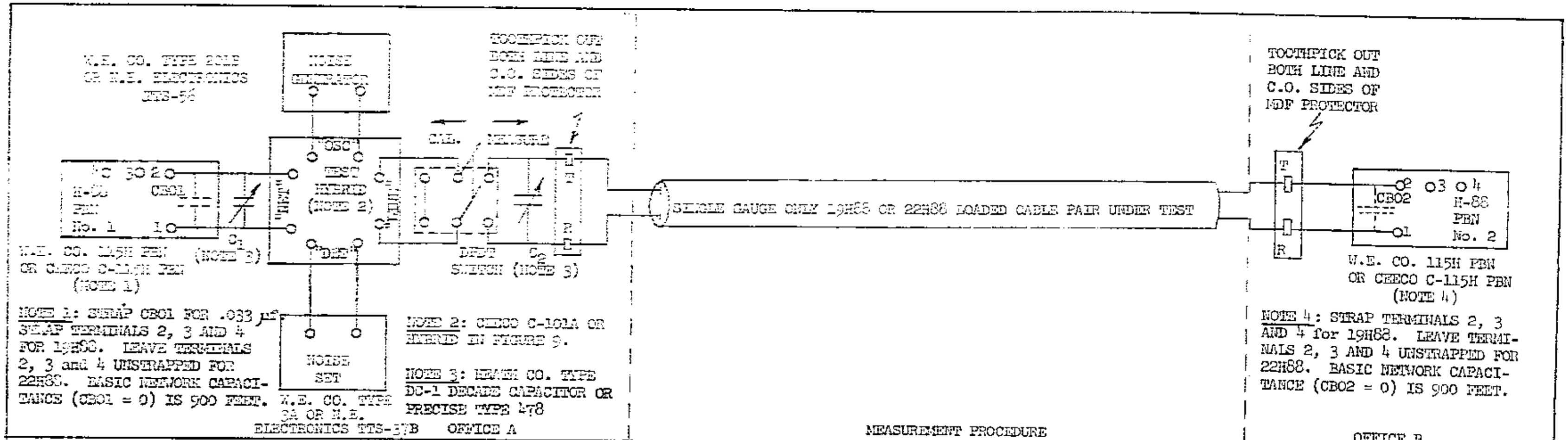
<u>Measuring at the D-66 end</u>

1. If gauge is uniform, that is all 19 gauge or all 22 gauge for both the D-66 and H-88 cables, use the measuring procedure in Figure 15.
2. If gauges are mixed, use measurement procedure of Figure 16.

<u>Measuring at the H-88 end</u>

3. If the gauge is uniform, that is all 19 gauge or all 22 gauge for both the D-66 and H-88 cables, use the measuring procedure in Figure 18.
4. If gauges are mixed, use measurement procedure of Figure 19.

FIGURE 17. ECHO STRUCTURAL RETURN LOSS MEASUREMENT OF D-66/H-88 LOADED CABLE USING THE D-66/H-88 JUNCTION IMPEDANCE COMPENSATOR



MEASUREMENT PROCEDURE

DO NOT ATTEMPT MEASUREMENTS BEFORE READING ENTIRE PARAGRAPH 8

1. Calibrate the 3A NMS by itself and the 201B by itself before proceeding with the measurement according to calibration instructions.

2. Connect the test equipment and cable pair under test as shown above. Make certain that terminals 4, 5 and 6 in PBN Nos. 1 and 2 are strapped (shorted) for 19-gauge and left unstrapped for 22 gauge.

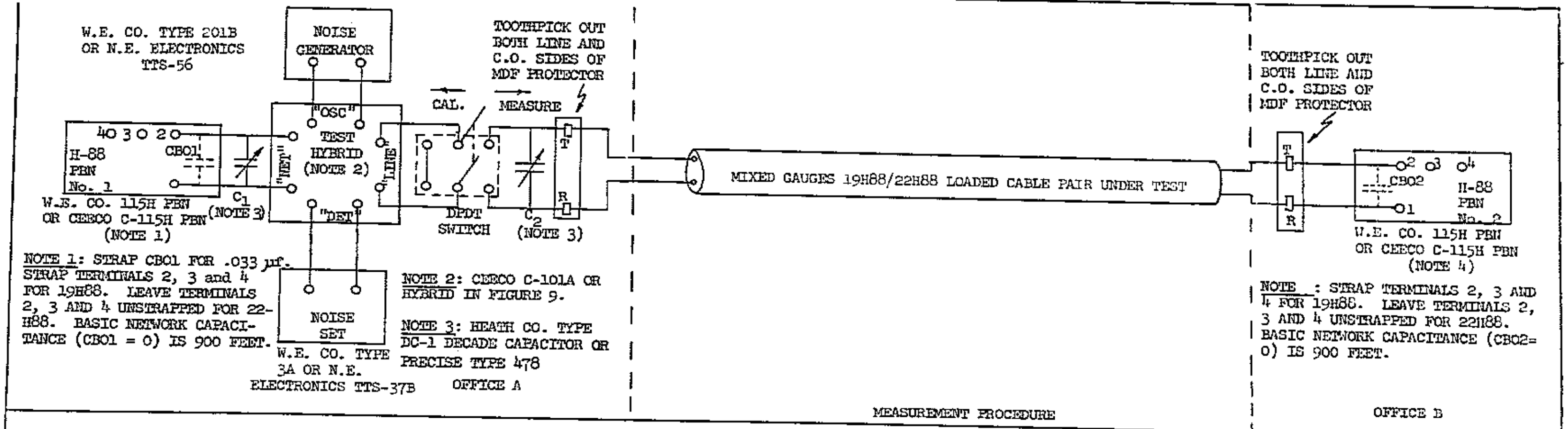
3. Set CB01 in PBN No. 1 to .033 µf. Set CB02 to build out PBN No. 2 to same value as physical length of cable end section. (Remember! 900 feet of this is already in the basic net of the PBN.) Set C_2 to build-out cable end section to 3000' total.

4. Throw DPDT switch to "CALIBRATE" position. Set "OUTPUT ATTEN." pad of 201B noise generator to the 8 db position and note the reading on the 3A NMS. 3A should read 89 dbrn-C. (Function switch of 3A must be in "NM 600" position and "C-Message Network" must be plugged in.) If 3A reads slightly higher or lower than this adjust "OUTPUT ATTEN." pad of 201B until the 89 dbrn-C is obtained on the 3A NMS. This completes calibration. Throw DPDT switch to "MEASURE" position. Do not change 201B output level control.

5. Read dbrn-C reading in 3A NMS. Vary C_2 and/or C_1 until lowest (best) reading is obtained in 3A NMS. This is the best reading and it is the one which should be recorded. Also vary the C_3 at the far end. See if reading on 3A gets lower (better). If it does record this reading. If not, record the best reading (varying C_3 will normally have no effect on the 3A NMS if the circuit has a loss of 5 db or greater).

6. The echo structural return loss (ESRL) in db is the difference between: [ESRL = 89 - dbrn-C reading, step (5)] in db.

FIGURE 18. ECHO STRUCTURAL RETURN LOSS MEASUREMENT (ESRL) OF ONE UNIFORM GAUGE ONLY FOR ENTIRE CIRCUIT LENGTH (19-H-88 ONLY OR 22-H-88 ONLY)



MEASUREMENT PROCEDURE

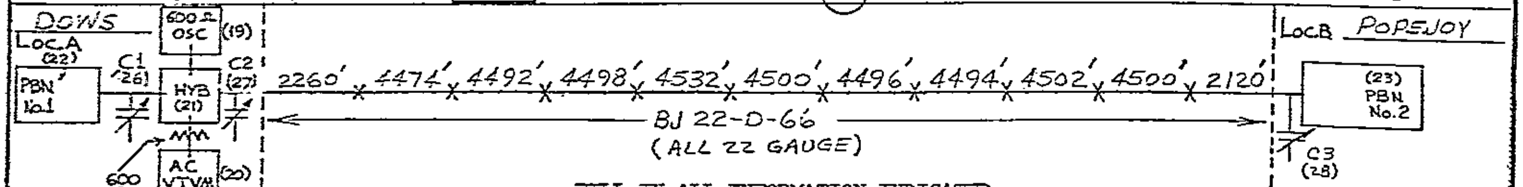
DO NOT ATTEMPT MEASUREMENTS BEFORE READING ENTIRE PARAGRAPH 8

1. Calibrate the 3A NMS by itself and the 201B by itself before proceeding with measurement according to calibration instructions.
2. Connect the test equipment and cable pair as shown above.
3. Throw DPDT switch to "CALIBRATE" position. Set "OUTPUT ATTEN." pad of 201B noise generator to the 8 db position and note the reading on the 3A NMS. The 3A should read 89 dbrn-C. (Function switch of 3A NMS must be on "NM 600" position and "C-Message Network" must be plugged in.) If 3A reads slightly higher or lower than this, adjust "OUTPUT ATTEN." pad of 201B until the 89 dbrn-C is obtained on the 3A. This completes calibration. Throw DPDT switch to "MEASURE" position. Do not change 201B output level pad.
4. Set CB01 in PBN No. 1 to .033 µf. Set CB02 to build out PBN No. 2 to same value as physical length of cable end section. (Remember! 900 feet of this is already in the basic net of the PBN.) Set C_2 to build-out cable end section to 3000' total.
5. Read dbrn-C reading in 3A NMS. Vary C_2 and/or C_1 until lowest (best) reading is obtained on 3A. Next, vary the gauge of PBN No. 1 and PBN No. 2 until the reading on 3A becomes the lowest possible. (This procedure involves varying C_1, C_2, gauge of PBN No. 1 and No. 2 until the combination is found which produces the lowest reading on the 3A NMS.) The lowest reading on the 3A is the reading to record.
6. The echo structural return loss (ESRL) in db is: [ESRL = 89 - dbrn-C reading, step (5)] in db.

FIGURE 19. ECHO STRUCTURAL RETURN LOSS (ESRL) MEASUREMENT OF H-88 LOADED CABLES WITH MIXED 19 AND 22 GAUGES

DATA SHEET - SINGLE FREQUENCY STRUCTURAL RETURN LOSS (SFSRL) FOR D-66 LOADING

(1) REA PROJ. DESIGN. IOWA 501-D (2) TRK.GROUP DOWS TO ALDEN (3) TOLL, EAS, SPEC. (Circle One)
(4) MEASURING BETWEEN DOWS TO POPEJOY (5) TRUNK NO. LOC. A ___, LOC. B ___ (6) PAIR NO. LOC. A 6, LOC. B 6
(7) TEMP. AIR ___ °F (If Aerial), GD. ___ °F (If Buried) (8) TESTERS PGL, HPP (9) DATE MEASMS. 7/14/53
In line diagram below show: (10) Type of loading system, (11) All gauges and length of each, (12) As-build length of each full-loading section, (13) As-built length of each end-section, (14) CBO, amount and location, (15) Junction Compensator, if used, (16) Plant buried or aerial, (17) Plant new or existing, (18) Age of plant if existing.



FILL IN ALL INFORMATION INDICATED

NOTE 1: FOR ALL EXAMPLES- D-66

The "3000 CYCLE BAND" is between 300 and 3000 cps.

The "3400 CYCLE BAND" is between 300 and 3400 cps.

EQPT. TYPE
(19) OSC HP 200J
(20) AC-VTVM HP 400L
(21) HYB A.L. 15139
(22) PBN NO.1 SEE 7/53
(23) PBN NO.2 SEE 7/53

PBN NO.1
(24) GA 22

PBN NO.2
(25) GA 22

OTHER
(26) C_1 0 MF
(27) C_2 0 MF
(28) C_3 0 MF
(29) OSC. CAL. LEV.[1] +7.0 DBM

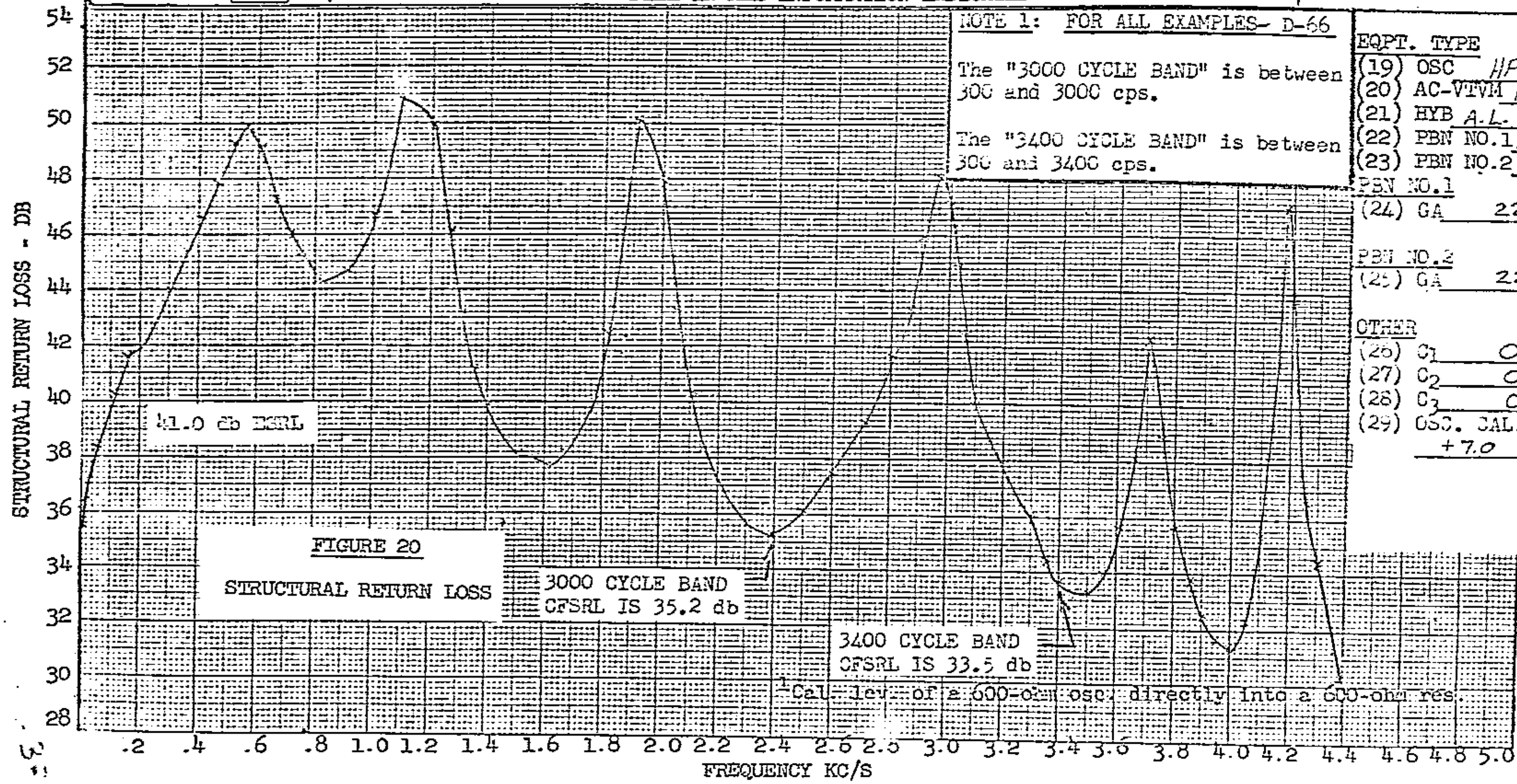
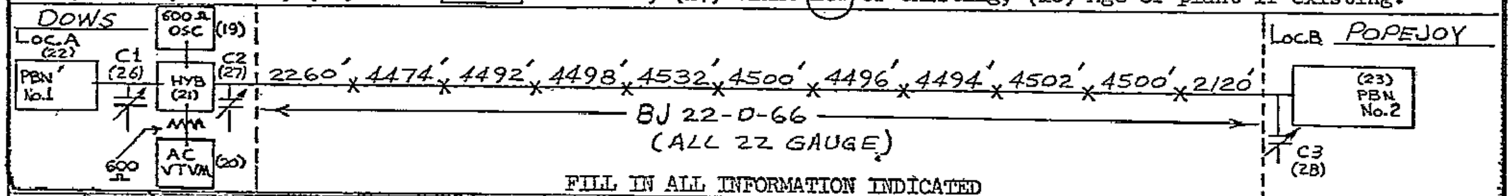


FIGURE 20
STRUCTURAL RETURN LOSS

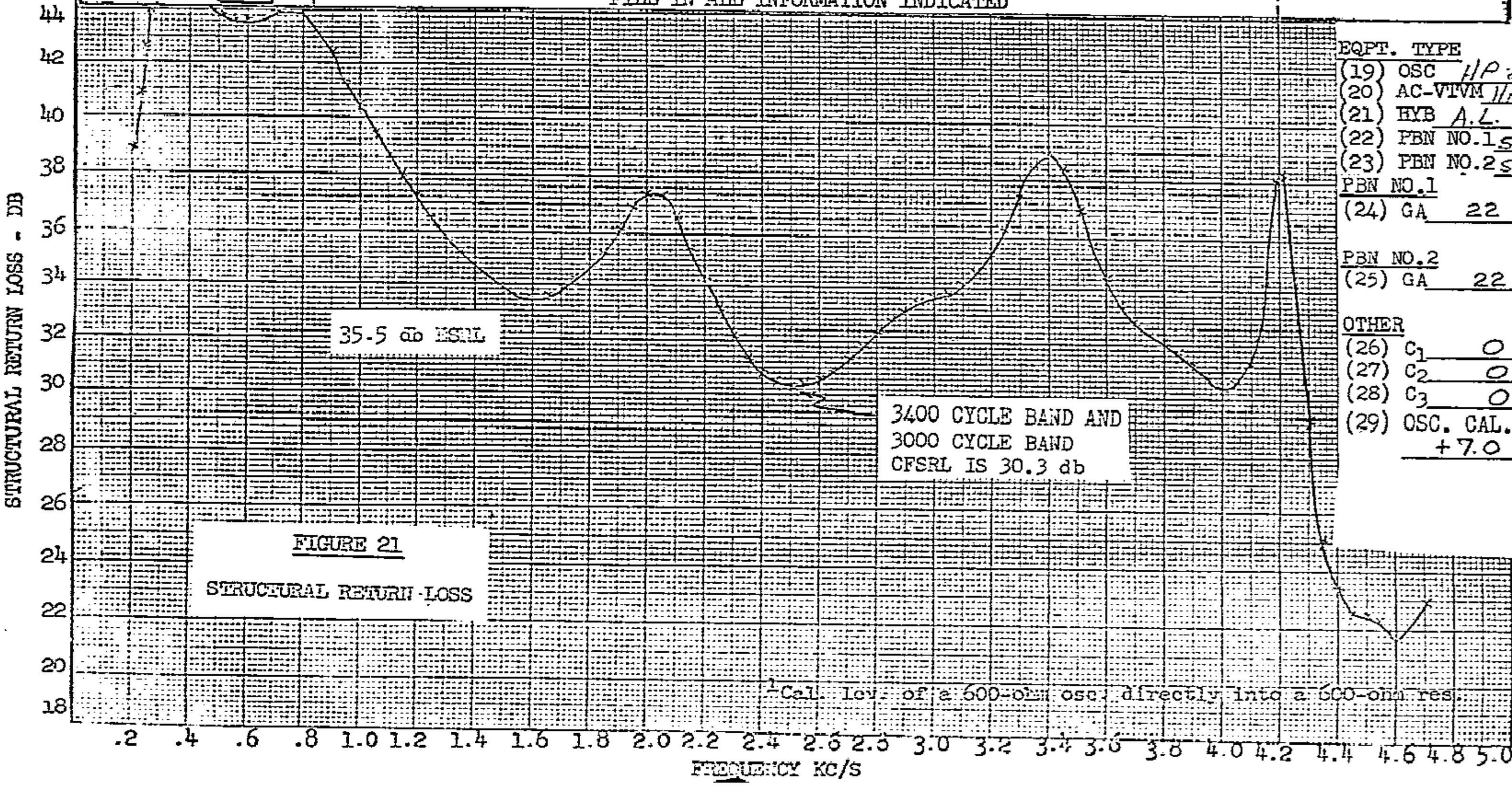
[1] Cal. lev. of a 600-ohm osc. directly into a 600-ohm res.

DATA SHEET - SINGLE FREQUENCY STRUCTURAL RETURN LOSS (SFSRL) FOR D-66 LOADING

(1) REA PROJ. DESIGN. IOWA 501-D (2) TRK.GROUP DOWS TO ALDEN (3) TOLL, EAS, SPEC. (Circle One)
(4) MEASURING BETWEEN DOWS TO POPEJOY (5) TRUNK NO. LOC. A ___, LOC. B ___ (6) PAIR NO. LOC. A 2, LOC.B ___
(7) TEMP. AIR ___ °F (IF Aerial), GD. ___ °F (If Buried) (8) TESTERS ECL, JTP (9) DATE MEASMS. 7/14/63
In line diagram below show: (10) Type of loading system, (11) All gauges and length of each, (12) As-build length of each full-loading section, (13) As-built length of each end-section, (14) CBO, amount and location, (15) Junction Compensator, if used, (16) Plant buried or aerial, (17) Plant new or existing, (18) Age of plant if existing.



FILL IN ALL INFORMATION INDICATED



EQPT. TYPE
(19) OSC HP 200J
(20) AC-VTVM HP 400L
(21) HYB A.L. 15189
(22) PBN NO.1 SEE FIG 3
(23) PBN NO.2 SEE FIG 3

PBN NO.1
(24) GA 22

PBN NO.2
(25) GA 22

OTHER
(26) C_1 0 MF
(27) C_2 0 MF
(28) C_3 0 MF
(29) OSC. CAL. LEV.[1] +7.0 DBM

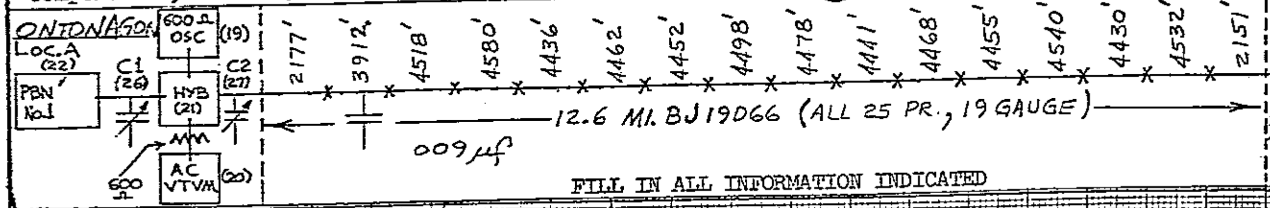
FIGURE 21

STRUCTURAL RETURN LOSS

[1] Cal. lev. of a 600-ohm osc. directly into a 600-ohm res.

DATA SHEET - SINGLE FREQUENCY STRUCTURAL RETURN LOSS (SFSRL) FOR D-66 LOADING

(1) REA PROJ. DESIGN. *MICHIGAN 529 A* (2) TRK.GROUP *ONTONAGON* TO *IRON MTN* (3) TOLL, EAS, SPEC. (Circle One)
(4) MEASURING BETWEEN *ONTONAGON* TO *ROCKLAND* (5) TRUNK NO. LOC. A *5P*, LOC. B *5P* (6) PAIR NO. LOC. A *21*, LOC. B *21*
(7) TEMP. AIR ____ °F (IF Aerial), GD. ____ °F (If Buried) (8) TESTERS *PGL, JAP* (9) DATE MEASMS. *8/19/65*
In line diagram below show: (10) Type of loading system, (11) All gauges and length of each, (12) As-build length of each full-loading section, (13) As-built length of each end-section, (14) CBO, amount and location, (15) Junction Compensator, if used, (16) Plant buried or aerial, (17) Plant new or existing, (18) Age of plant if existing.



FILL IN ALL INFORMATION INDICATED

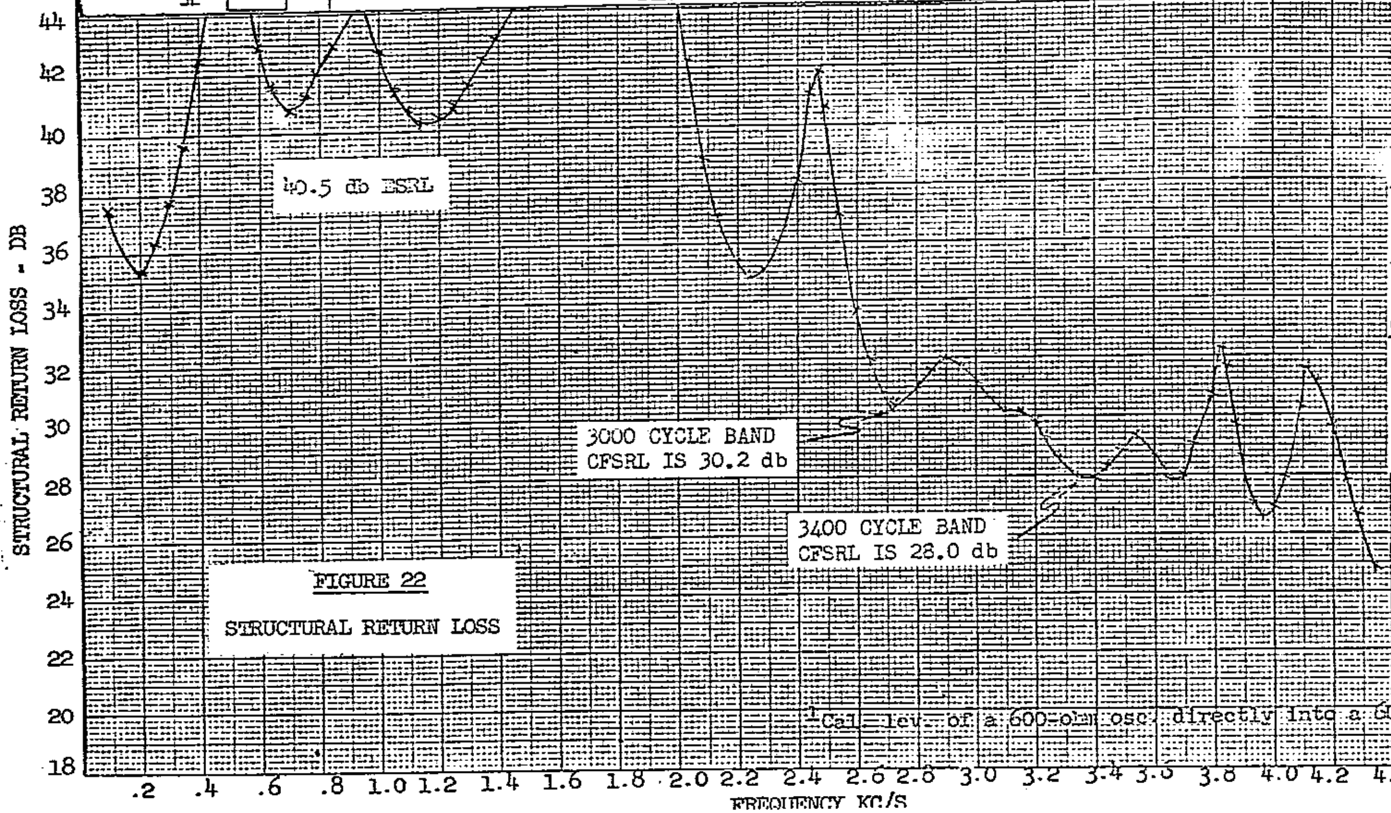


FIGURE 22

STRUCTURAL RETURN LOSS

EQPT. TYPE
(19) OSC *H.P. 200J*
(20) AC-VTVM *H.P. 400L*
(21) HYB *I. 15199*
(22) PBN NO.1 *SEE FIG 3*
(23) PBN NO.2 *SEE FIG 3*

PBN NO.1
(24) GA *19*

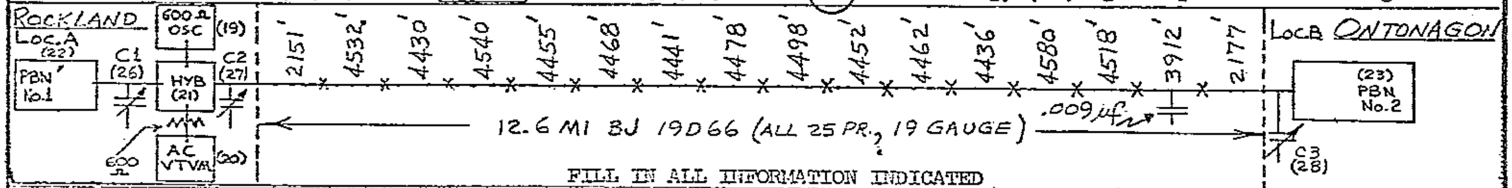
PBN NO.2
(25) GA *19*

OTHER
(26) C_1 *0* MF
(27) C_2 *.003* MF
(28) C_3 *0* MF
(29) OSC. CAL. LEV.[1] *+7.0* DBM

[1] Cal. lev. of a 600-ohm osc. directly into a 600-ohm res.

DATA SHEET - SINGLE FREQUENCY STRUCTURAL RETURN LOSS (SFSRL) FOR D-66 LOADING

(1) REA PROJ. DESIGN. MICHIGAN 529 A (2) TRK.GROUP ONTONAGON TO IRON MTN (3) TOLL, EAS, SPEC. (Circle One)
(4) MEASURING BETWEEN ROCKLAND TO ONTONAGON (5) TRUNK NO. LOC. A SP, LOC. B SP (6) PAIR NO. LOC. A 21, LOC. B 21
(7) TEMP. AIR ______ °F (IF Aerial), GD. ____ °F (If Buried) (8) TESTERS GGL, JKR (9) DATE MEASMS. 8/19/63
In line diagram below show: (10) Type of loading system, (11) All gauges and length of each, (12) As-build length of each full-loading section, (13) As-built length of each end-section, (14) CBO, amount and location, (15) Junction Compensator, if used, (16) Plant buried or aerial, (17) Plant new or existing, (18) Age of plant if existing.



FILL IN ALL INFORMATION INDICATED

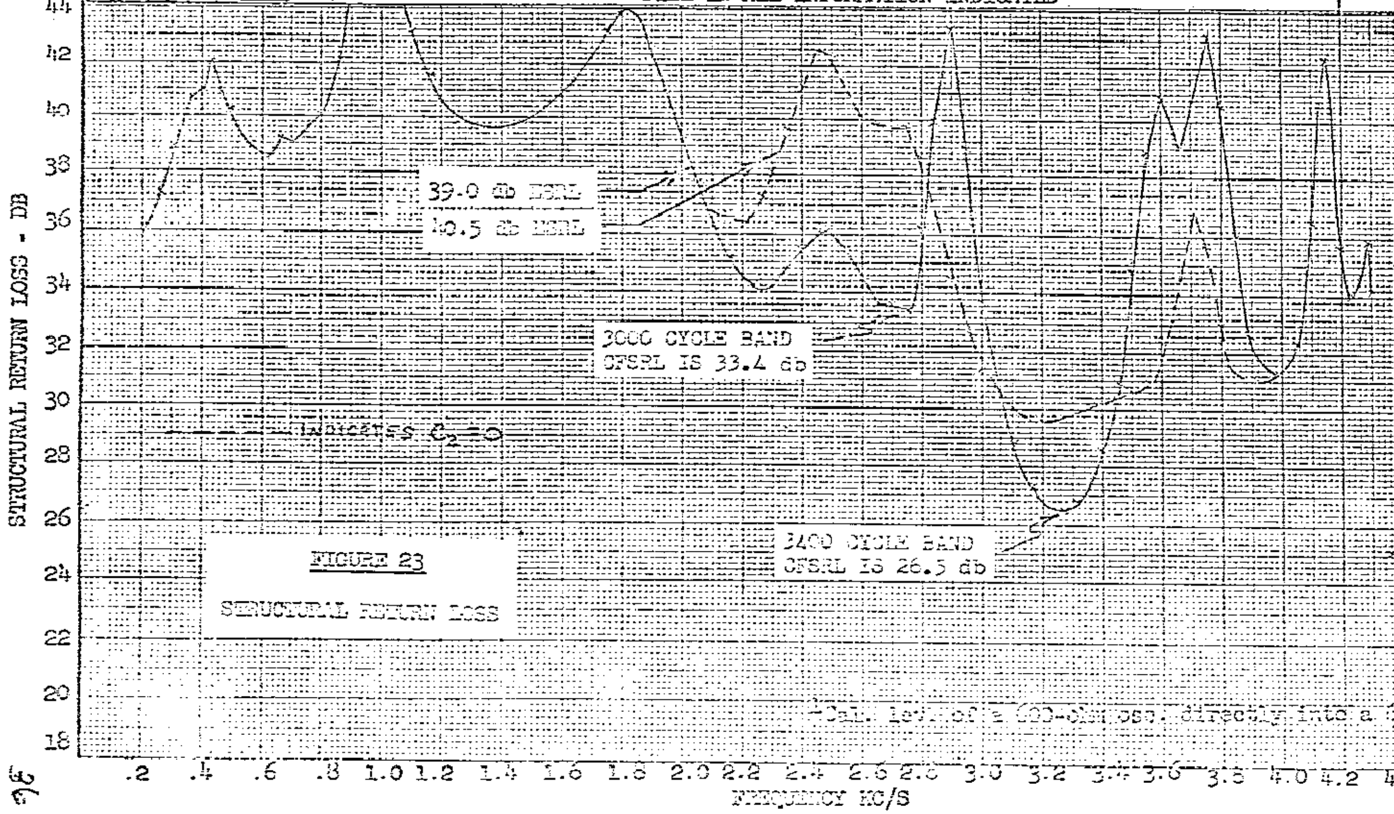


FIGURE 23

STRUCTURAL RETURN LOSS

EQPT. TYPE
(19) OSC HP 200 J
(20) AC-VTVM HP 400L
(21) HYB AL 15189
(22) PBN NO. 1 SEE 71G3
(23) PBN NO. 2 SEE 71G3

PBN NO. 1
(24) GA 19

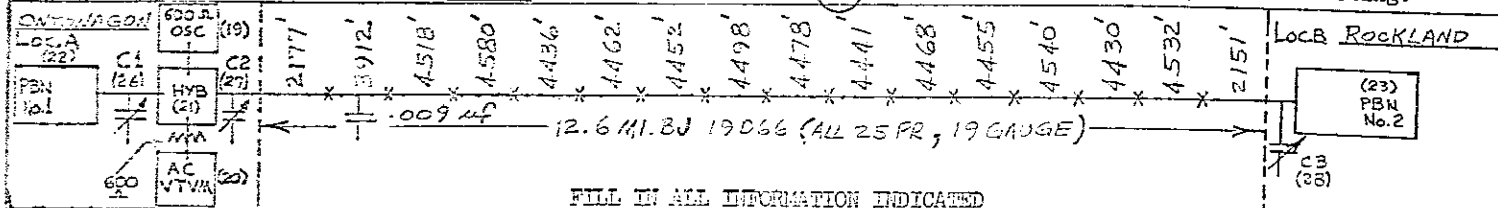
PBN NO. 2
(25) GA 19

OTHER
(26) C_1 0 MF
(27) C_2 .001 MF
(28) C_3 0 MF
(29) OSC. CAL. LEV. 1 +7.0 DBM

DATA SHEET - SINGLE FREQUENCY STRUCTURAL RETURN LOSS (SFSRL) FOR D-66 LOADING

(1) REA PROJ. DESIGN. *MICHIGAN 529 A* (2) TRK.GROUP *ONTONAGON* TO *[illegible]* (3) TOLL, EAS, SPEC. (Circle One)
(4) MEASURING BETWEEN *ONTONAGON* TO *ROCKLAND* (5) TRUNK NO. LOC. A *SE*, LOC. B *SE* (6) PAIR NO. LOC. A *8*, LOC.B *8*
(7) TEMP. AIR ______ °F (If Aerial), GD. ____ °F (If Buried) (8) TESTERS *[illegible]* (9) DATE MEASMS. *8/19/63*

In line diagram below show: (10) Type of loading system, (11) All gauges and length of each, (12) As-build length of each full-loading section, (13) As-built length of each end-section, (14) CBO, amount and location, (15) Junction Compensator, if used, (16) Plant buried or aerial, (17) Plant new or existing, (18) Age of plant if existing.



FILL IN ALL INFORMATION INDICATED

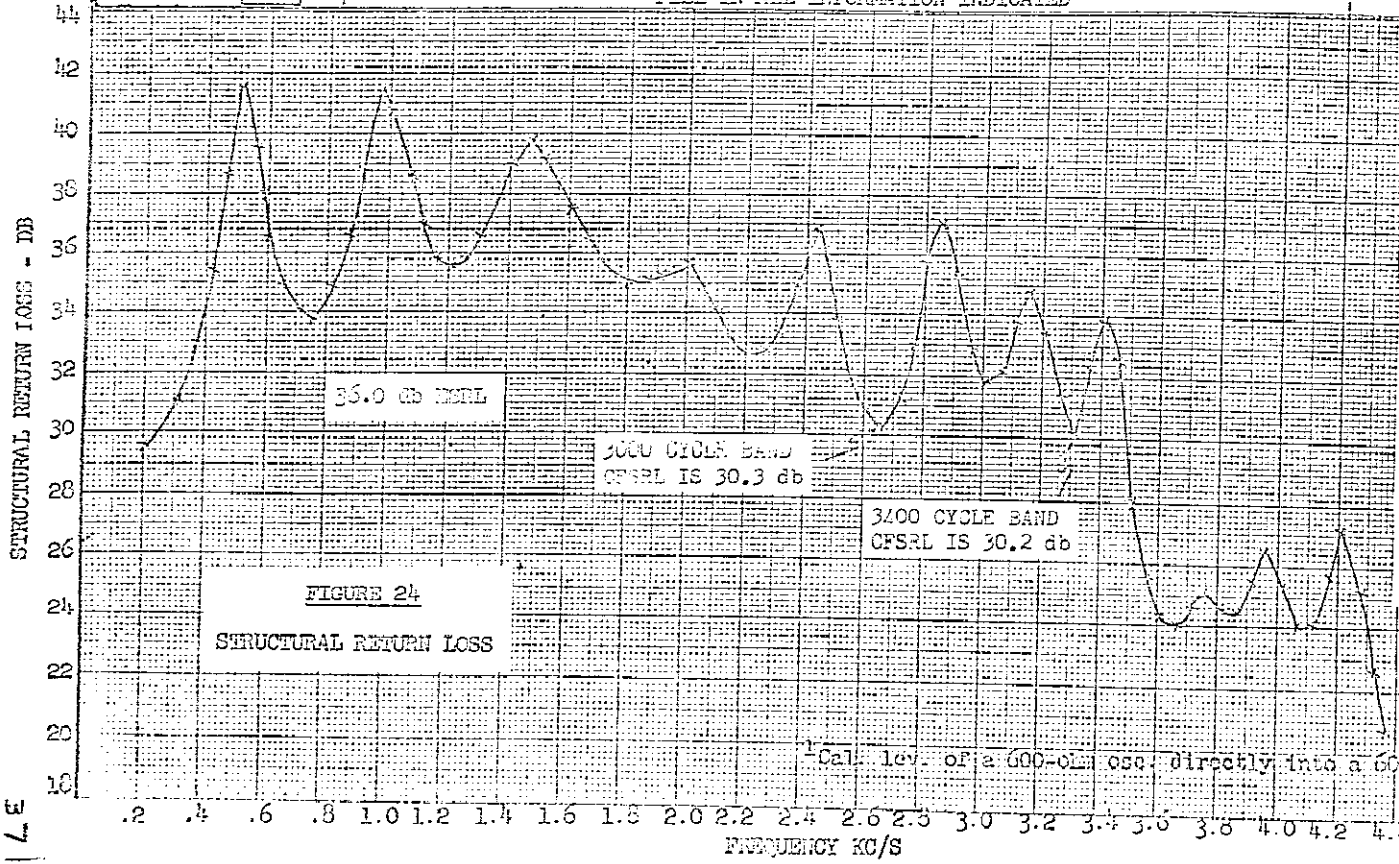


FIGURE 24

STRUCTURAL RETURN LOSS

EQPT. TYPE
(19) OSC *H.P. 200 J*
(20) AC-VTVM *H.P. 400 L*
(21) HYB *A.L. 15189*
(22) PBN NO.1 *SEE 7IG3*
(23) PBN NO.2 *SEE 7IG3*

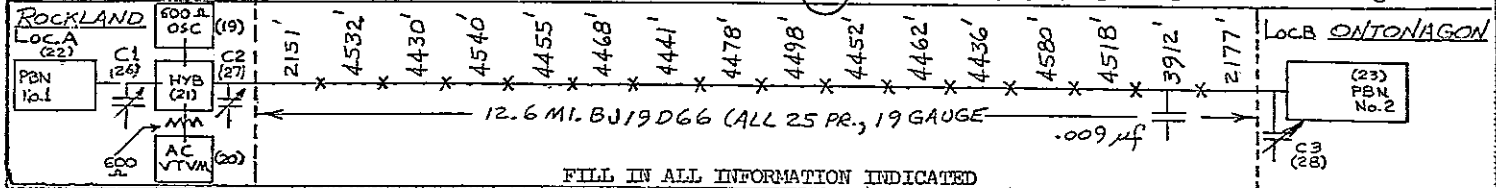
PBN NO.1
(24) GA *19*

PBN NO.2
(25) GA *19*

OTHER
(26) C_1 *0* MF,
(27) C_2 *.003* MF
(28) C_3 *0* MF
(29) OSC. CAL. LEV.[1] ______ DBM

DATA SHEET - SINGLE FREQUENCY STRUCTURAL RETURN LOSS (SFSRL) FOR D-66 LOADING

(1) REA PROJ. DESIGN. MICHIGAN 529 A (2) TRK.GROUP ONTONAGON TO IRON MTN (3) TOLL, EAS, SPEC. (Circle One)
(4) MEASURING BETWEEN ROCKLAND TO ONTONAGON (5) TRUNK NO. LOC. A SP, LOC. B SP (6) PAIR NO. LOC. A 8, LOC. B 8
(7) TEMP. AIR ______ °F (IF Aerial), GD. 65 °F (If Buried) (8) TESTERS PGL, JHP (9) DATE MEASMS. 8/19/63
In line diagram below show: (10) Type of loading system, (11) All gauges and length of each, (12) As-build length of each full-loading section, (13) As-built length of each end-section, (14) CBO, amount and location, (15) Junction Compensator, if used, (16) Plant buried or aerial, (17) Plant new or existing, (18) Age of plant if existing.



FILL IN ALL INFORMATION INDICATED

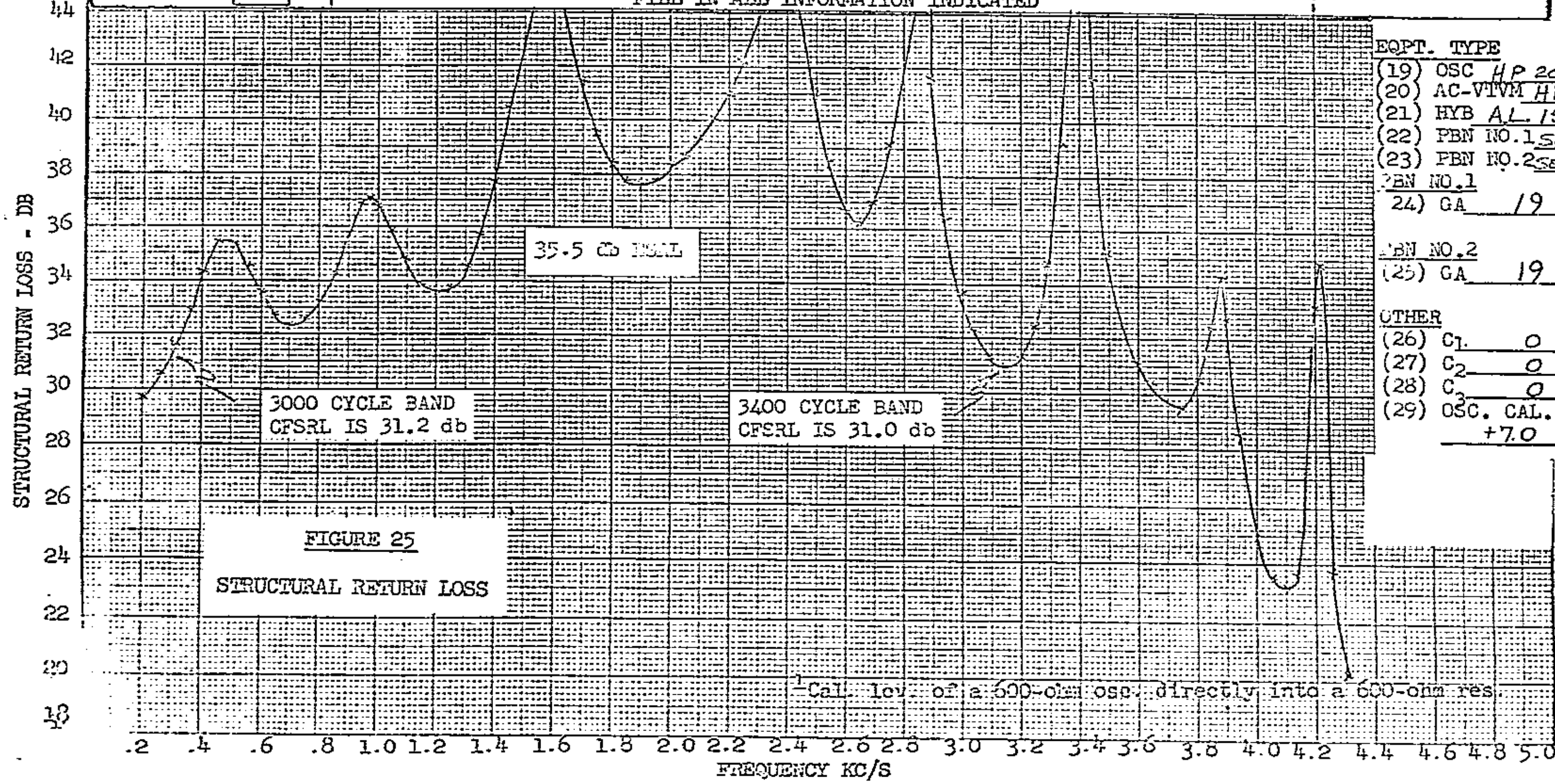


FIGURE 25

STRUCTURAL RETURN LOSS

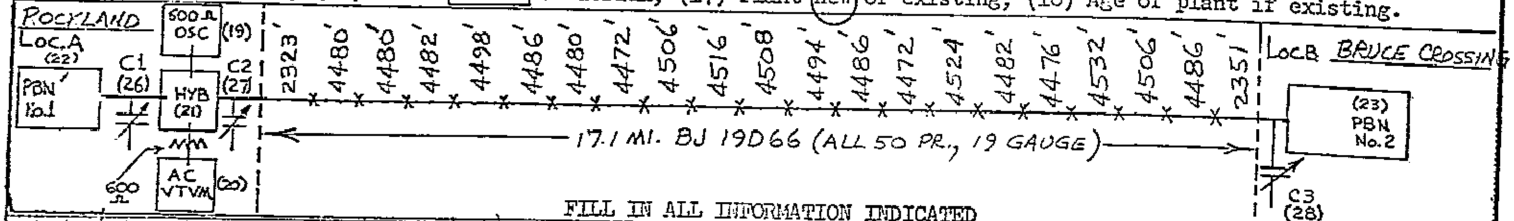
EQPT. TYPE
(19) OSC HP 200 J
(20) AC-VTVM HP 400 D
(21) HYB A.L. 15189
(22) PBN NO.1 SEE 7163
(23) PBN NO.2 SEE 7163
PBN NO.1
(24) GA 19

PBN NO.2
(25) GA 19

OTHER
(26) C_1 0 MF
(27) C_2 0 MF
(28) C_3 0 MF
(29) OSC. CAL. LEV. [1] +7.0 DBM

DATA SHEET - SINGLE FREQUENCY STRUCTURAL RETURN LOSS (SFSRL) FOR D-66 LOADING

(1) REA PROJ. DESIGN. MICHIGAN 529 A (2) TRK.GROUP ROCKLAND TO BRUCE CROSS (3) TOLL, EAS, SPEC. (Circle One)
(4) MEASURING BETWEEN ROCKLAND TO BRUCE CROSS. (5) TRUNK NO. LOC. A SP, LOC. B SP (6) PAIR NO. LOC. A 11, LOC.B 11
(7) TEMP. AIR ____ °F (IF Aerial), GD. ____ °F (If Buried) (8) TESTERS [illegible] (9) DATE MEASMS. 8/20/63
In line diagram below show: (10) Type of loading system, (11) All gauges and length of each, (12) As-build length of each full-loading section, (13) As-built length of each end-section, (14) CBO, amount and location, (15) Junction Compensator, if used, (16) Plant buried or aerial, (17) Plant new or existing, (18) Age of plant if existing.



FILL IN ALL INFORMATION INDICATED

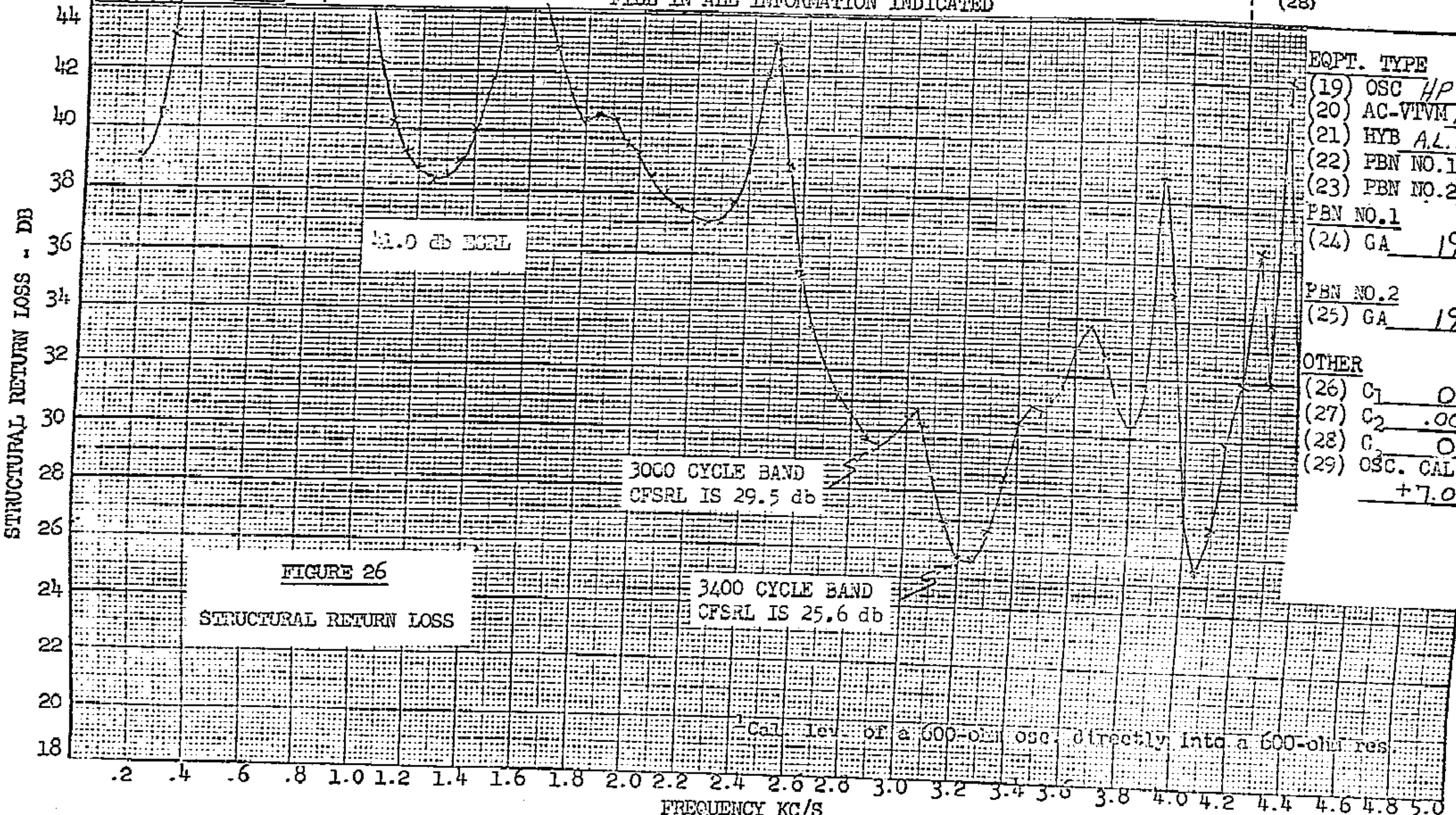


FIGURE 26

STRUCTURAL RETURN LOSS

EQPT. TYPE
(19) OSC HP 200J
(20) AC-VTVM HP400L
(21) HYB A.L.15189
(22) PBN NO.1 SEE FIG3
(23) PBN NO.2 SEE FIG3

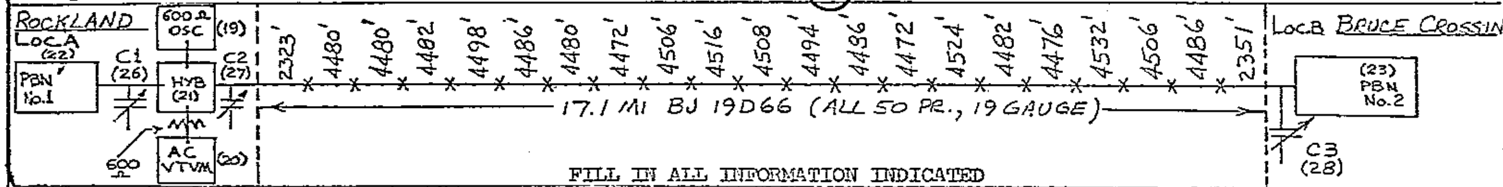
PBN NO.1
(24) GA 19

PBN NO.2
(25) GA 19

OTHER
(26) C_1 0 MF
(27) C_2 .001 MF
(28) C_3 0 MF
(29) OSC. CAL. LEV. 1 +7.0 DBM

DATA SHEET - SINGLE FREQUENCY STRUCTURAL RETURN LOSS (SFSRL) FOR D-66 LOADING

(1) REA PROJ. DESIGN. MICHIGAN 529-A (2) TRK.GROUP ONTONAGON TO IRON MTN. (3) TOLL, EAS, SPEC. (Circle One)
(4) MEASURING BETWEEN ROCKLAND TO BRUCE CROSS. (5) TRUNK NO. LOC. A SP, LOC. B SP (6) PAIR NO. LOC. A 20, LOC. B 20
(7) TEMP. AIR ____ °F (IF Aerial), GD. ____ °F (If Buried) (8) TESTERS [illegible] (9) DATE MEASMS. 8/20/65
In line diagram below show: (10) Type of loading system, (11) All gauges and length of each, (12) As-build length of each full-loading section, (13) As-built length of each end-section, (14) CBO, amount and location, (15) Junction Compensator, if used, (16) Plant buried or aerial, (17) Plant new or existing, (18) Age of plant if existing.



FILL IN ALL INFORMATION INDICATED

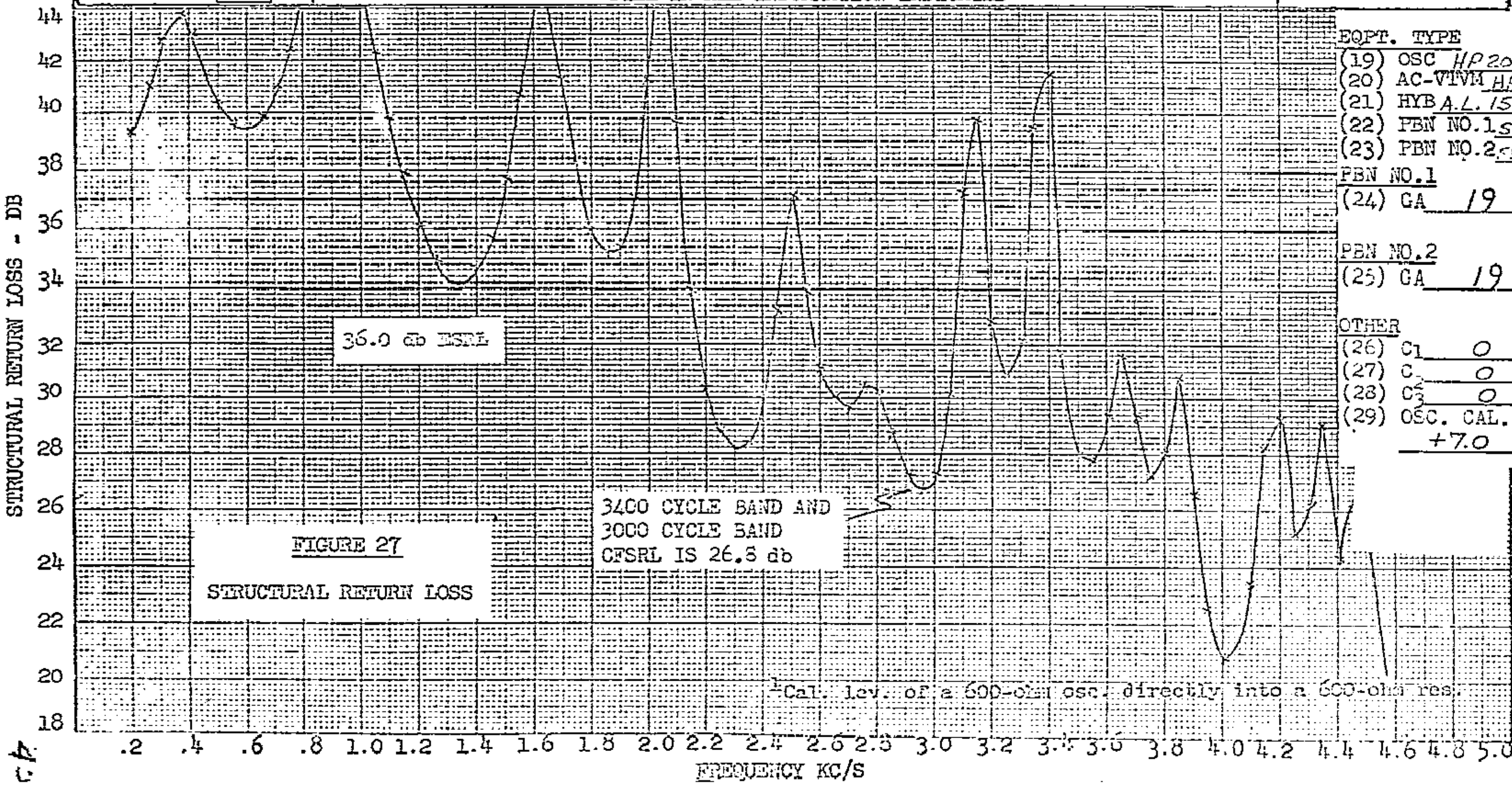


FIGURE 27

STRUCTURAL RETURN LOSS

[1]Cal. lev. of a 600-ohm osc. directly into a 600-ohm res.

EQPT. TYPE
(19) OSC HP 200J
(20) AC-VTVM HP 400L
(21) HYB A.L. 15189
(22) PBN NO.1 SEE 7163
(23) PBN NO.2 SEE 7163

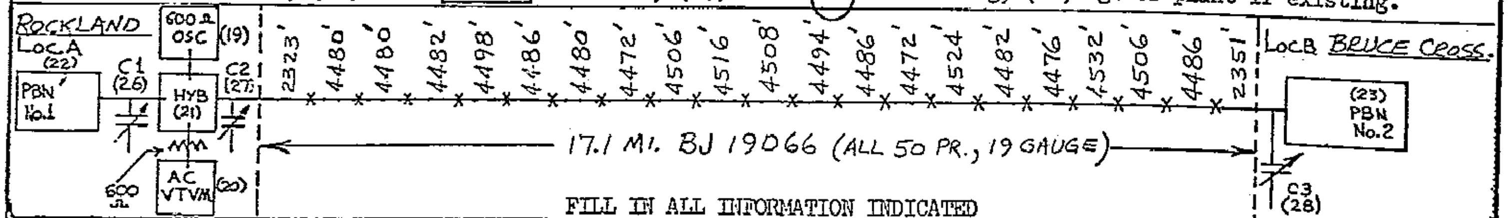
PBN NO.1
(24) GA 19

PBN NO.2
(25) GA 19

OTHER
(26) C1 0 MF
(27) C2 0 MF
(28) C3 0 MF
(29) OSC. CAL. LEV. 1 +7.0 DBM

DATA SHEET - SINGLE FREQUENCY STRUCTURAL RETURN LOSS (SFSRL) FOR D-66 LOADING

(1) REA PROJ. DESIGN. MICHIGAN 529 A (2) TRK.GROUP ROCKLAND TO BRUCE CROSS (3) TOLL, EAS, SPEC. (Circle One)
(4) MEASURING BETWEEN ROCKLAND TO BRUCE CROSS (5) TRUNK NO. LOC. A SP, LOC. B SP (6) PAIR NO. LOC. A 21, LOC. B 21
(7) TEMP. AIR ______ °F (IF Aerial), GD. ____ °F (If Buried) (8) TESTERS GGL, JKP (9) DATE MEASMS. 8/20/63
In line diagram below show: (10) Type of loading system, (11) All gauges and length of each, (12) As-build length of each full-loading section, (13) As-built length of each end-section, (14) CBO, amount and location, (15) Junction Compensator, if used, (16) Plant buried or aerial, (17) Plant new or existing, (18) Age of plant if existing.



FILL IN ALL INFORMATION INDICATED

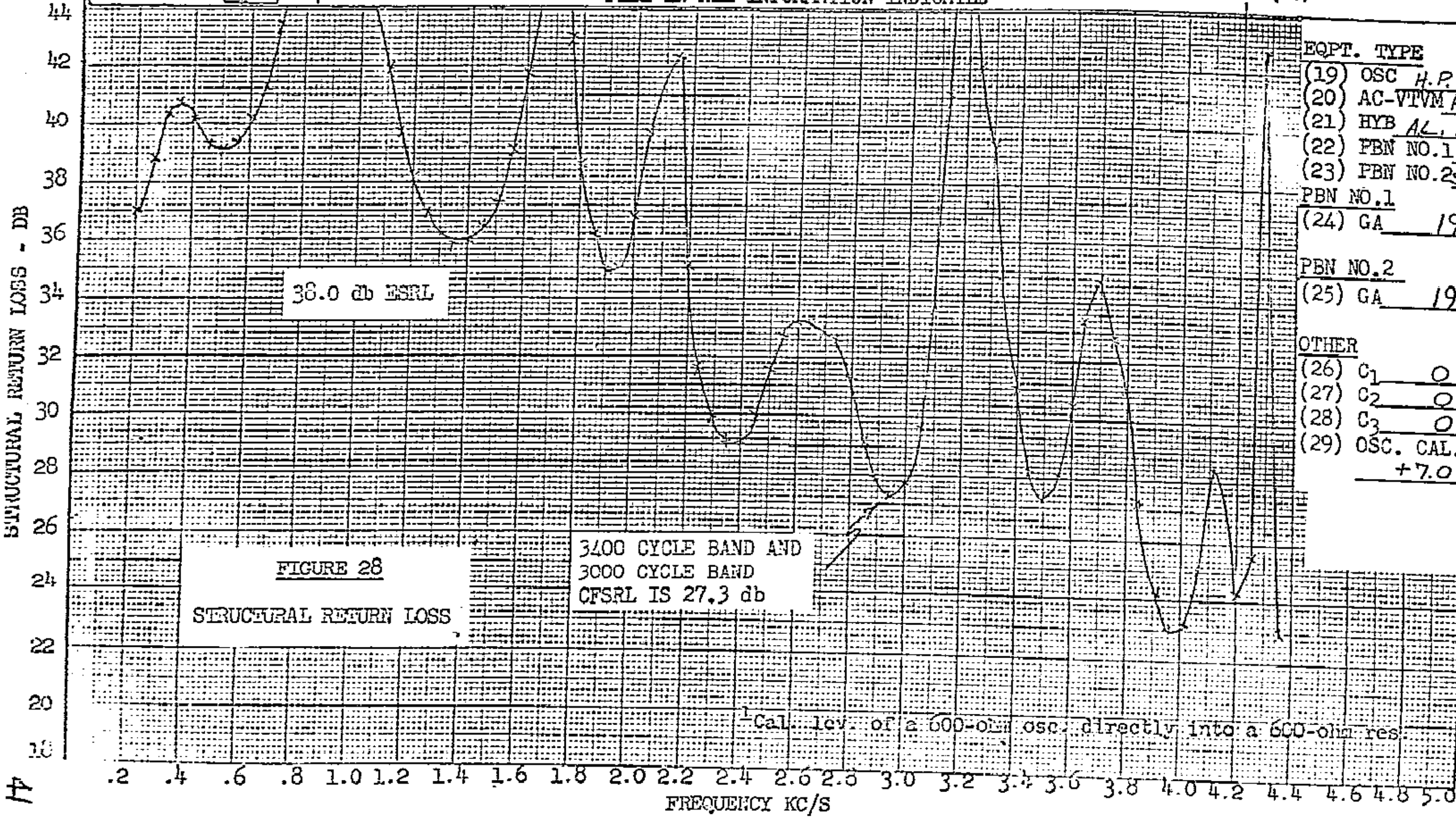


FIGURE 28

STRUCTURAL RETURN LOSS

EQPT. TYPE
(19) OSC H.P. 200 J
(20) AC-VTVM H.P. 400 L
(21) HYB AL. 15189
(22) PBN NO.1 SEE FIG 3
(23) PBN NO.2 SEE FIG 3

PBN NO.1
(24) GA 19

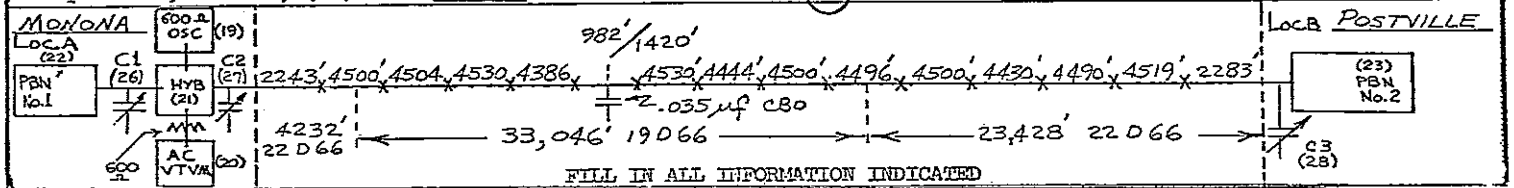
PBN NO.2
(25) GA 19

OTHER
(26) C_1 0 MF
(27) C_2 0 MF
(28) C_3 0 MF
(29) OSC. CAL. LEV. [1] +7.0 DBM

[1] Cal. lev. of a 600-ohm osc. directly into a 600-ohm res.

DATA SHEET - SINGLE FREQUENCY STRUCTURAL RETURN LOSS (SFSRL) FOR D-66 LOADING

(1) REA PROJ. DESIGN. IowA 583 -A (2) TRK.GROUP MONONA TO POSTVILLE (3) TOLL, EAS, SPEC. (Circle One)
(4) MEASURING BETWEEN MONONA TO POSTVILLE (5) TRUNK NO. LOC. A 1, LOC. B 1 (6) PAIR NO. LOC. A 251, LOC. B 1251
(7) TEMP. AIR ____ °F (IF Aerial), GD. ____ °F (If Buried) (8) TESTERS PGL, JHP (9) DATE MEASMS. 7/10/63
In line diagram below show: (10) Type of loading system, (11) All gauges and length of each, (12) As-build length of each full-loading section, (13) As-built length of each end-section, (14) CBO, amount and location, (15) Junction Compensator, if used, (16) Plant buried or aerial, (17) Plant new or existing, (18) Age of plant if existing.



FILL IN ALL INFORMATION INDICATED

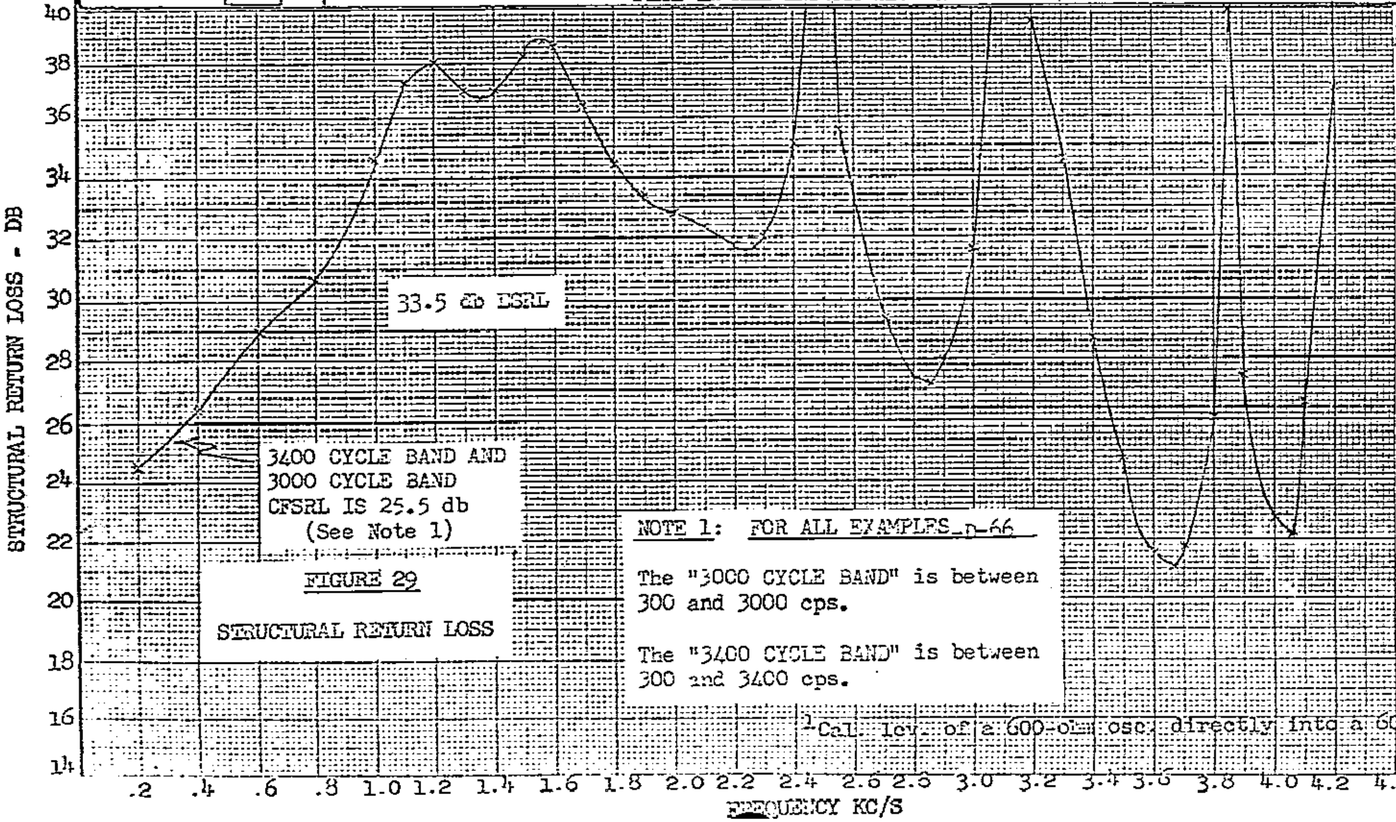


FIGURE 29

STRUCTURAL RETURN LOSS

NOTE 1: FOR ALL EXAMPLES D-66

The "3000 CYCLE BAND" is between 300 and 3000 cps.

The "3400 CYCLE BAND" is between 300 and 3400 cps.

EQPT. TYPE
(19) OSC HP 200 J
(20) AC-VTVM HP 400L
(21) HYB A.L. 15189
(22) PBN NO.1 SEE 71G3
(23) PBN NO.2 SEE 71G3

PBN NO.1
(24) GA 19

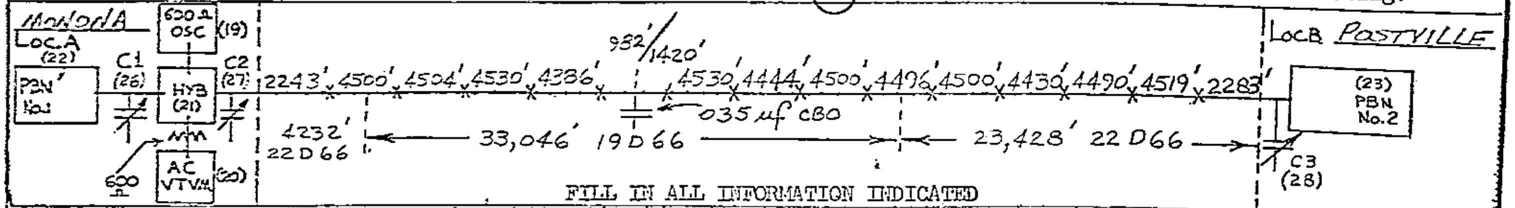
PBN NO.2
(25) GA 22

OTHER
(26) C_1 0 MF
(27) C_2 0 MF
(28) C_3 0 MF
(29) OSC. CAL. LEV. [1] +7.0 DBM

[1] Cal. lev. of a 600-ohm osc. directly into a 600-ohm res.

DATA SHEET - SINGLE FREQUENCY STRUCTURAL RETURN LOSS (SFSRL) FOR D-66 LOADING

(1) REA PROJ. DESIGN. IOWA 583-A (2) TRK.GROUP MONONA TO POSTVILLE (3) TOLL, EAS, SPEC. (Circle One)
(4) MEASURING BETWEEN MONONA TO POSTVILLE (5) TRUNK NO. LOC. A 8 LOC. B ___ (6) PAIR NO. LOC. A ___ LOC. B 1258
(7) TEMP. AIR ___ °F (IF Aerial), GD. ___ °F (If Buried) (8) TESTERS ___ (9) DATE MEASMS. 7/10/63
In line diagram below show: (10) Type of loading system, (11) All gauges and length of each, (12) As-build length of each full-loading section, (13) As-built length of each end-section, (14) CBO, amount and location, (15) Junction Compensator, if used, (16) Plant buried or aerial, (17) Plant new or existing, (18) Age of plant if existing.



FILL IN ALL INFORMATION INDICATED

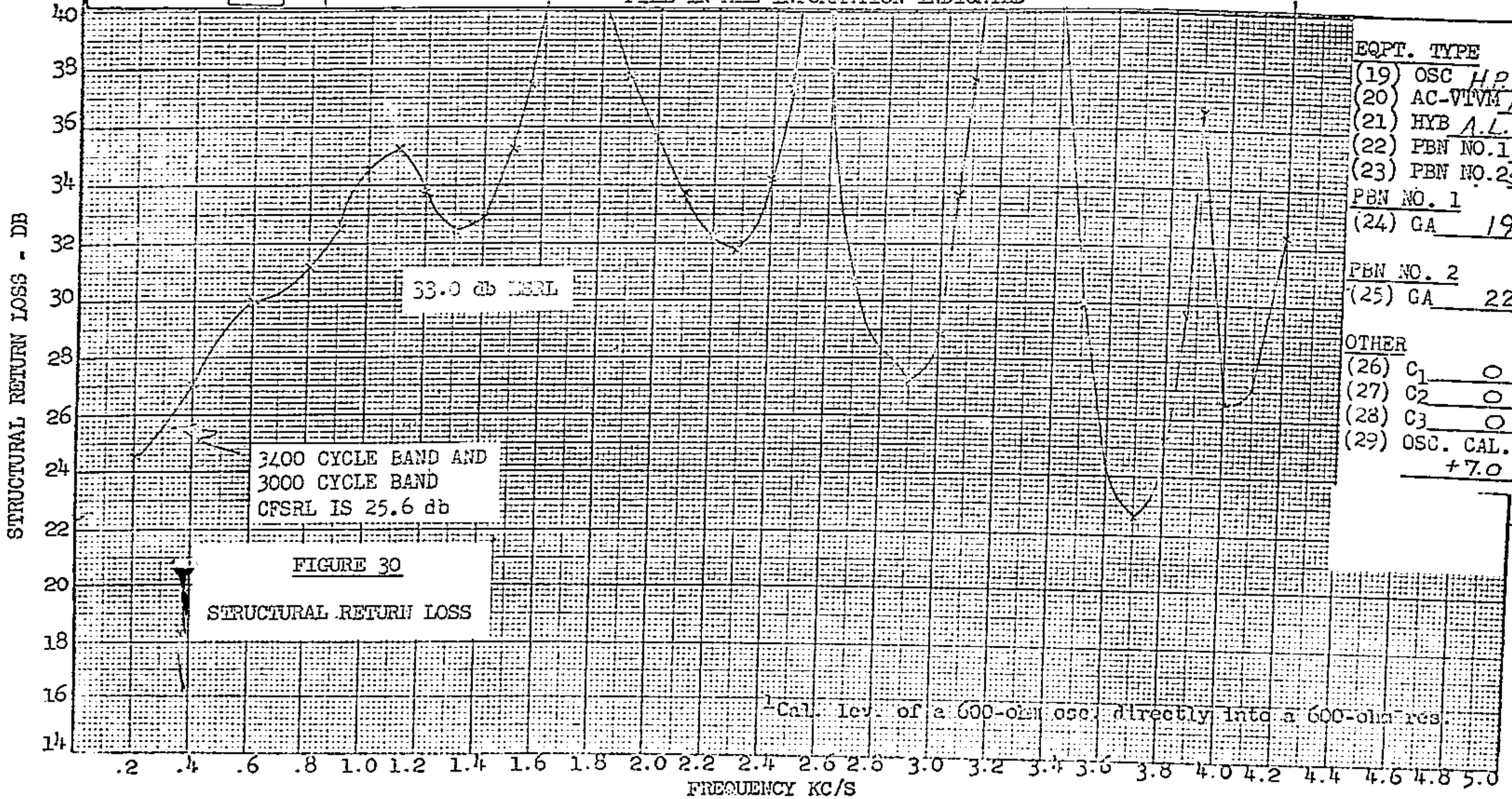


FIGURE 30

STRUCTURAL RETURN LOSS

EQPT. TYPE
(19) OSC HP200J
(20) AC-VTVM HP400L
(21) HYB A.L. 15189
(22) PBN NO.1 SEE FIG 3
(23) PBN NO.2 SEE FIG 3

PBN NO. 1
(24) GA 19

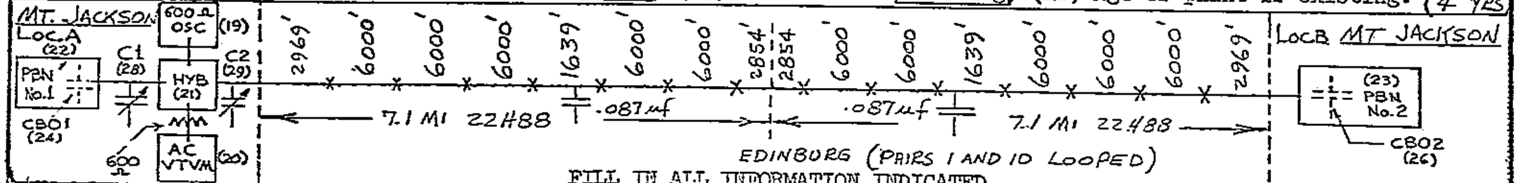
PBN NO. 2
(25) GA 22

OTHER
(26) C_1 0 MF
(27) C_2 0 MF
(28) C_3 0 MF
(29) OSC. CAL. LEV. 1 +7.0 DBM

1 Cal. lev. of a 600-ohm osc. directly into a 600-ohm res.

DATA SHEET - SINGLE FREQUENCY STRUCTURAL RETURN LOSS (SFSRL) FOR H-88 LOADING

(1) REA PROJ. DESIGN. VA.517 EDINBURG (2) TRK.GROUP MT JACKSON TO EDINBURG (3) TOLL, EAS, SPEC. (Circle One)
(4) MEASURING BETWEEN MT. JACKSON TO MT JACKSON (5) TRUNK NO. LOC. A 1.1, LOC. B 10,10 (6) PAIR NO. LOC. A ___, LOC.B ___
(7) TEMP. AIR ___ °F (IF Aerial), GD. ___ °F (If Buried) (8) TESTERS [illegible] (9) DATE MEASMS. 11/16/62
In line diagram below show: (10) Type of loading system, (11) All gauges and length of each, (12) As-build length of each full-loading section, (13) As-built length of each end-section, (14) CBO, amount and location, (15) Junction Compensator, if used, (16) Plant buried or aerial, (17) Plant new or existing, (18) Age of plant if existing. (4 YRS)



FILL IN ALL INFORMATION INDICATED

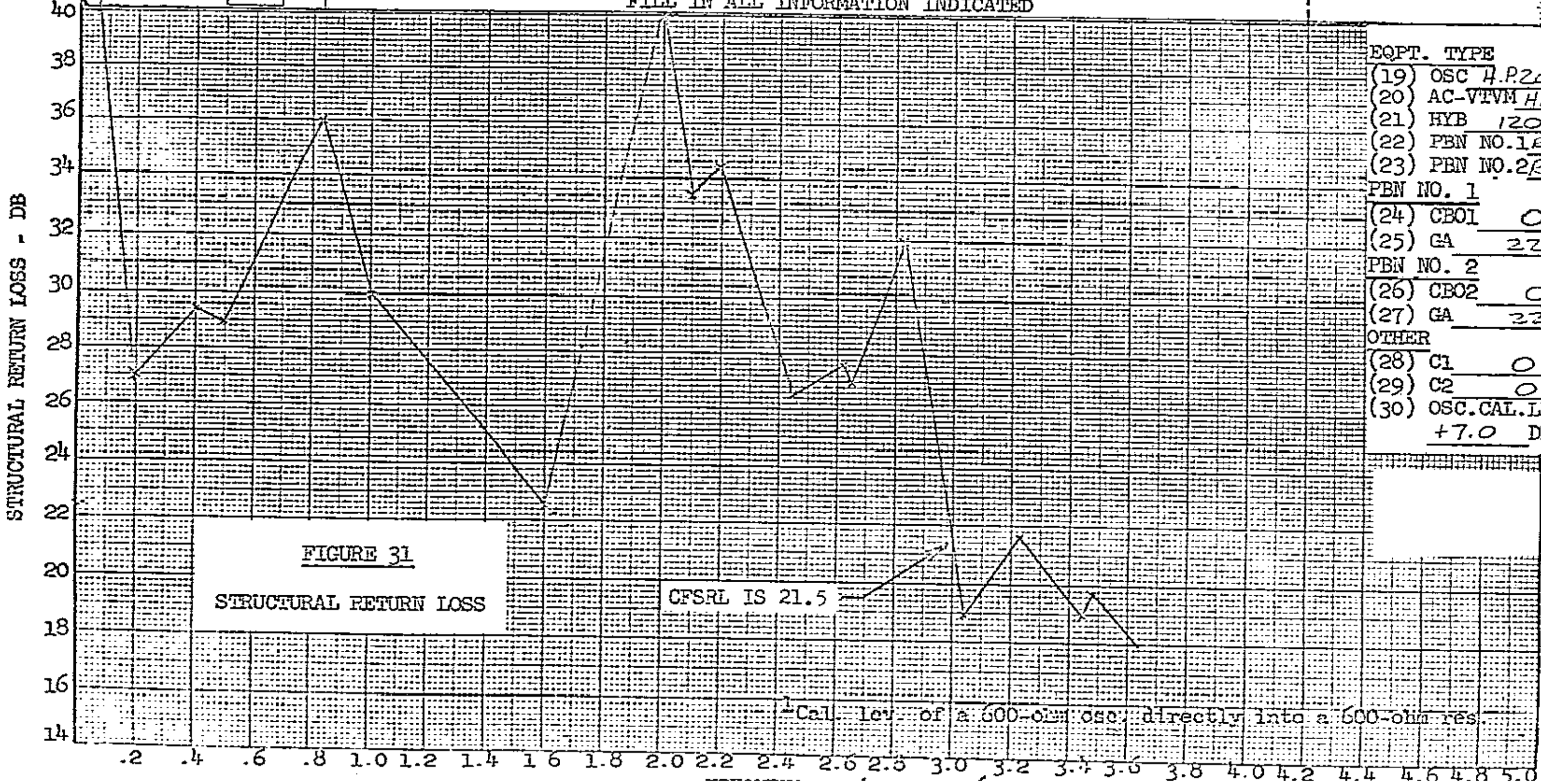


FIGURE 31

STRUCTURAL RETURN LOSS

EQPT. TYPE
(19) OSC H.P.200J
(20) AC-VTVM HP400L
(21) HYB 120 P
(22) PBN NO.1 REA-H-88
(23) PBN NO.2 REA-H-88

PBN NO. 1
(24) CBO1 0 MF
(25) GA 22

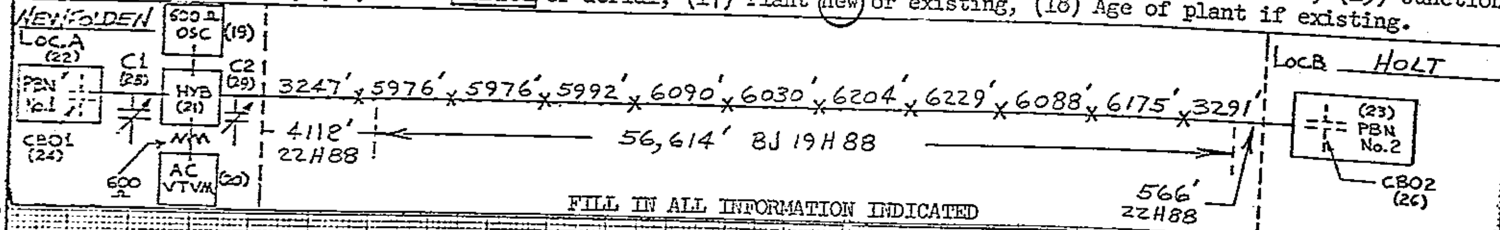
PBN NO. 2
(26) CBO2 0 MF
(27) GA 22

OTHER
(28) C1 0 MF
(29) C2 0 MF
(30) OSC.CAL.LEV.[1] +7.0 DBM

[1]Cal. lev. of a 600-ohm osc. directly into a 600-ohm res.

DATA SHEET - SINGLE FREQUENCY STRUCTURAL RETURN LOSS (SFSRL) FOR H-88 LOADING

(1) REA PROJ. DESIGN. MINN. 520 WIKSTROM (2) TRK.GROUP NEWFOLDEN TO HOLT (3) TOLL, EAS, SPEC. (Circle One)
(4) MEASURING BETWEEN NEWFOLDEN TO HOLT (5) TRUNK NO. LOC. A ___, LOC. B ___ (6) PAIR NO. LOC. A 13, LOC.B 32
(7) TEMP. AIR ____ °F (If Aerial), GD. 40 °F (If Buried) (8) TESTERS RGL, JTP (9) DATE MEASMS. 2/13/62
In line diagram below show: (10) Type of loading system, (11) All gauges and length of each, (12) As-build length of each full-loading section, (13) As-built length of each end-section, (14) CBO, amount and location, (15) Junction Compensator, if used, (16) Plant buried or aerial, (17) Plant new or existing, (18) Age of plant if existing.



FILL IN ALL INFORMATION INDICATED

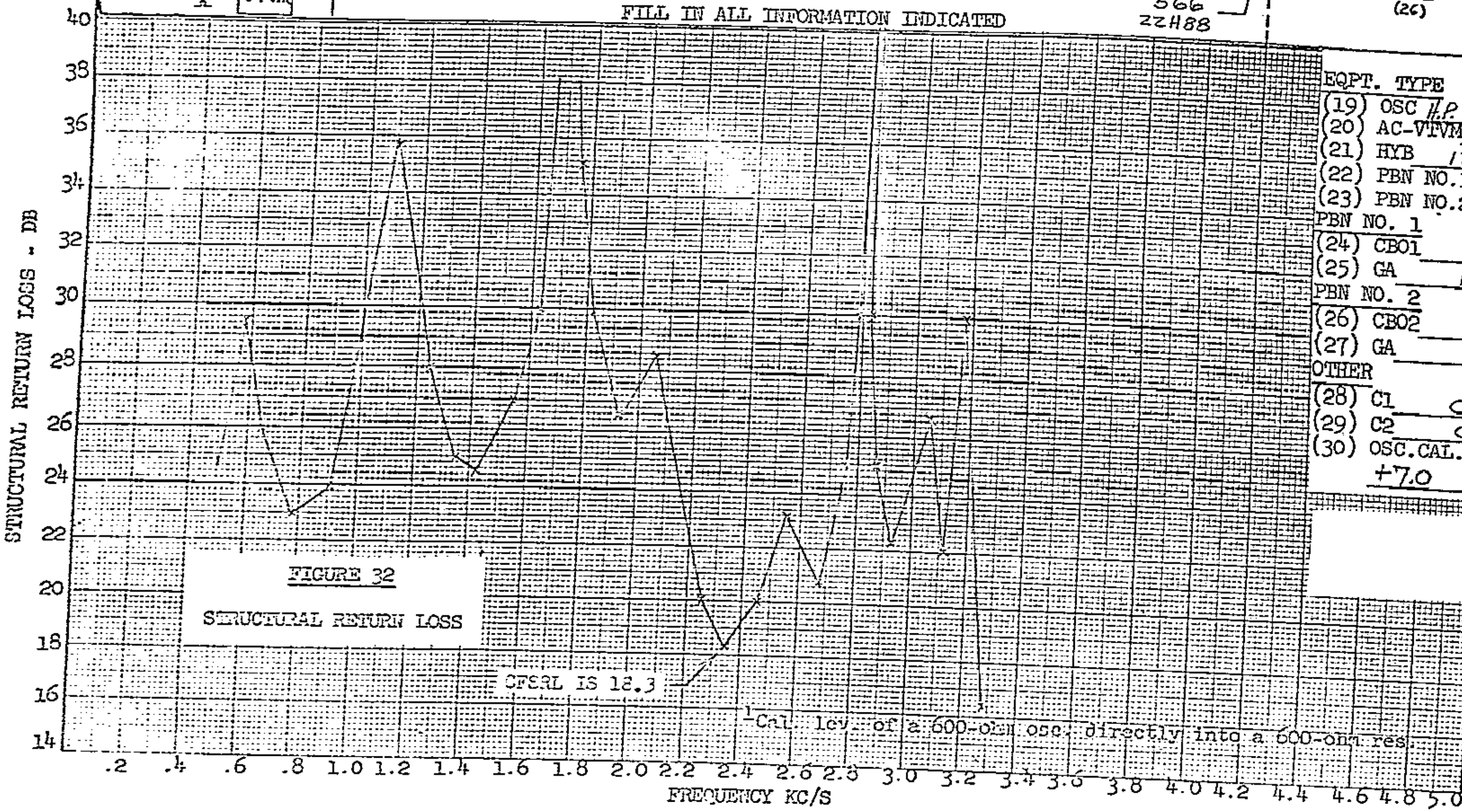


FIGURE 32

STRUCTURAL RETURN LOSS

EQPT. TYPE
(19) OSC H.P. 200 CD
(20) AC-VTVM H.P. 400D
(21) HYB 120P
(22) PBN NO.1 REA-H-88
(23) PBN NO.2 REA-H-88

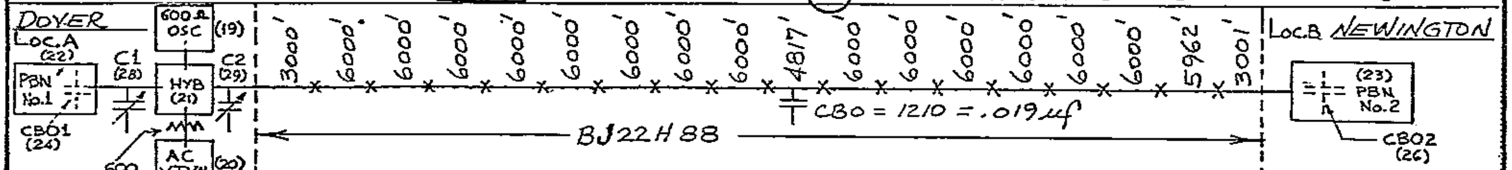
PBN NO. 1
(24) CBO1 0 MF
(25) GA 19

PBN NO. 2
(26) CBO2 0 MF
(27) GA 19

OTHER
(28) C1 0 MF
(29) C2 0 MF
(30) OSC.CAL.LEV.[1] +7.0 DBM

(1) REA PROJ. DESIGN. GA 534 PLANTERS (2) TRK.GROUP DOVER TO NEWINGTON (3) TOLL, EAS, SPEC. (Circle One)
(4) MEASURING BETWEEN DOVER TO NEWINGTON (5) TRUNK NO. LOC. A 3, LOC. B 3 (6) PAIR NO. LOC. A 3, LOC. B 3
(7) TEMP. AIR ____ °F (IF Aerial), GD. ____ °F (If Buried) (8) TESTERS GGL, TZM (9) DATE MEASMS. 10/25/62

In line diagram below show: (10) Type of loading system, (11) All gauges and length of each, (12) As-build length of each full-loading section, (13) As-built length of each end-section, (14) CBO, amount and location, (15) Junction Compensator, if used, (16) Plant buried or aerial, (17) Plant new or existing, (18) Age of plant if existing.



FILL IN ALL INFORMATION INDICATED

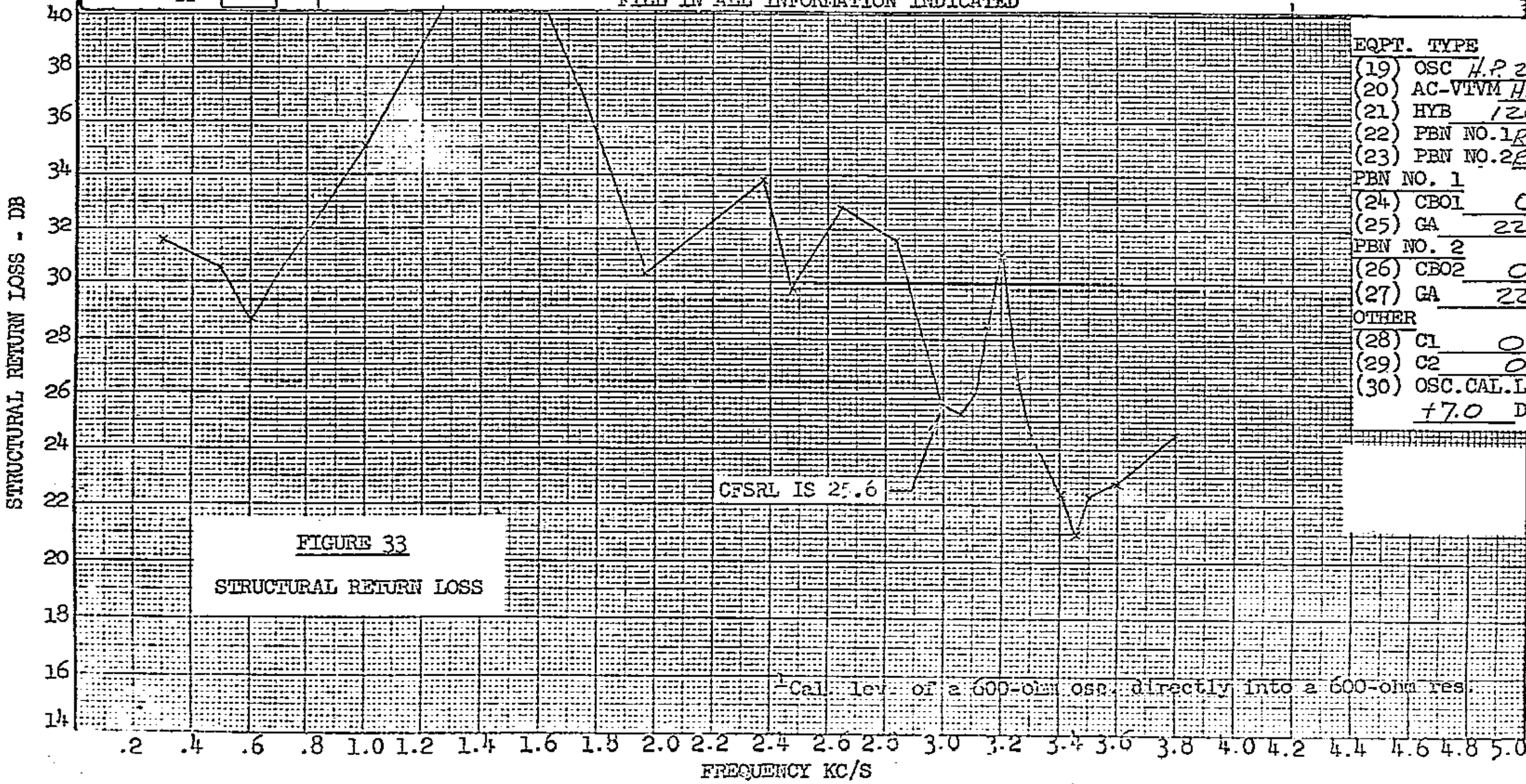


FIGURE 33

STRUCTURAL RETURN LOSS

EQPT. TYPE
(19) OSC H.P. 200J
(20) AC-VTVM H.P. 400L
(21) HYB 120 P
(22) PBN NO.1 REA H-88
(23) PBN NO.2 REA H-88

PBN NO. 1
(24) CBO1 0 MF
(25) GA 22

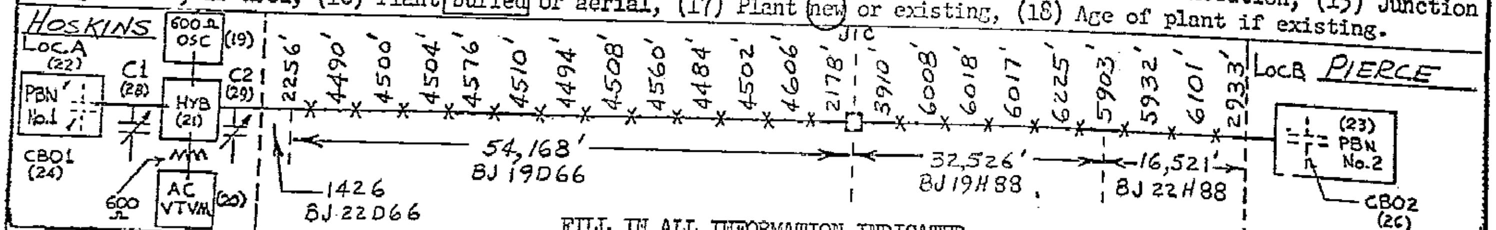
PBN NO. 2
(26) CBO2 0 MF
(27) GA 22

OTHER
(28) C1 0 MF
(29) C2 0 MF
(30) OSC.CAL.LEV.[1] +7.0 DBM

[1] Cal. lev. of a 600-ohm osc. directly into a 600-ohm res.

DATA SHEET - SINGLE FREQUENCY STRUCTURAL RETURN LOSS (SFSRL) FOR H-88 LOADING

(1) REA PROJ. DESIGN. NEBRASKA 536 B (2) TRK.GROUP HOSKINS TO PIERCE (3) TOLL, EAS, SPEC. (Circle One)
(4) MEASURING BETWEEN HOSKINS TO PIERCE (5) TRUNK NO. LOC. A 1, LOC. B 1 (6) PAIR NO. LOC. A 151, LOC. B 276
(7) TEMP. AIR 25 °F (IF Aerial), GD. 45 °F (If Buried) (8) TESTERS RAC, HA, ES. (9) DATE MEASMS. 2/6/64
In line diagram below show: (10) Type of loading system, (11) All gauges and length of each, (12) As-build length of each full-loading section, (13) As-built length of each end-section, (14) CBO, amount and location, (15) Junction Compensator, if used, (16) Plant buried or aerial, (17) Plant new or existing, (18) Age of plant if existing.



FILL IN ALL INFORMATION INDICATED

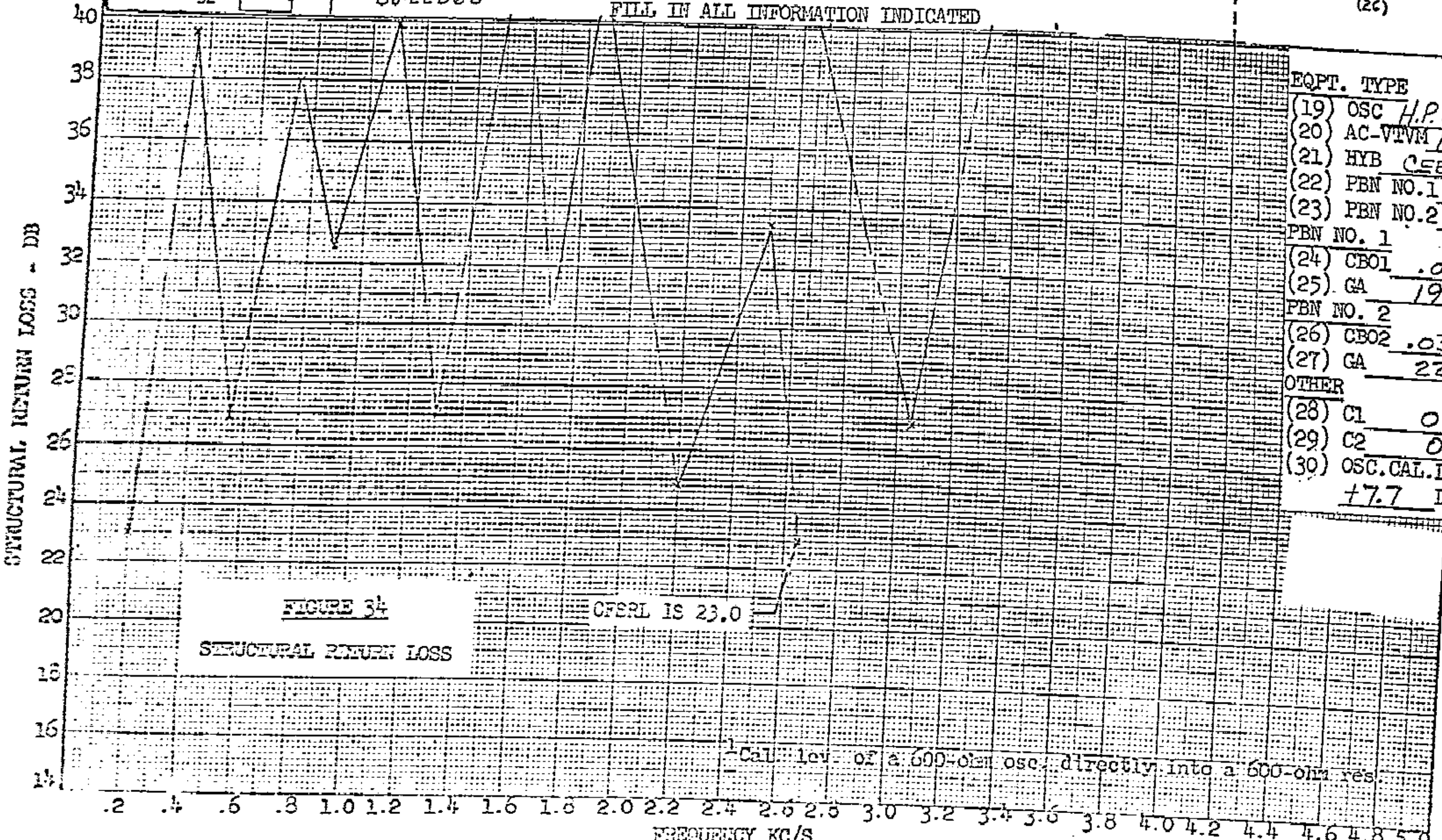
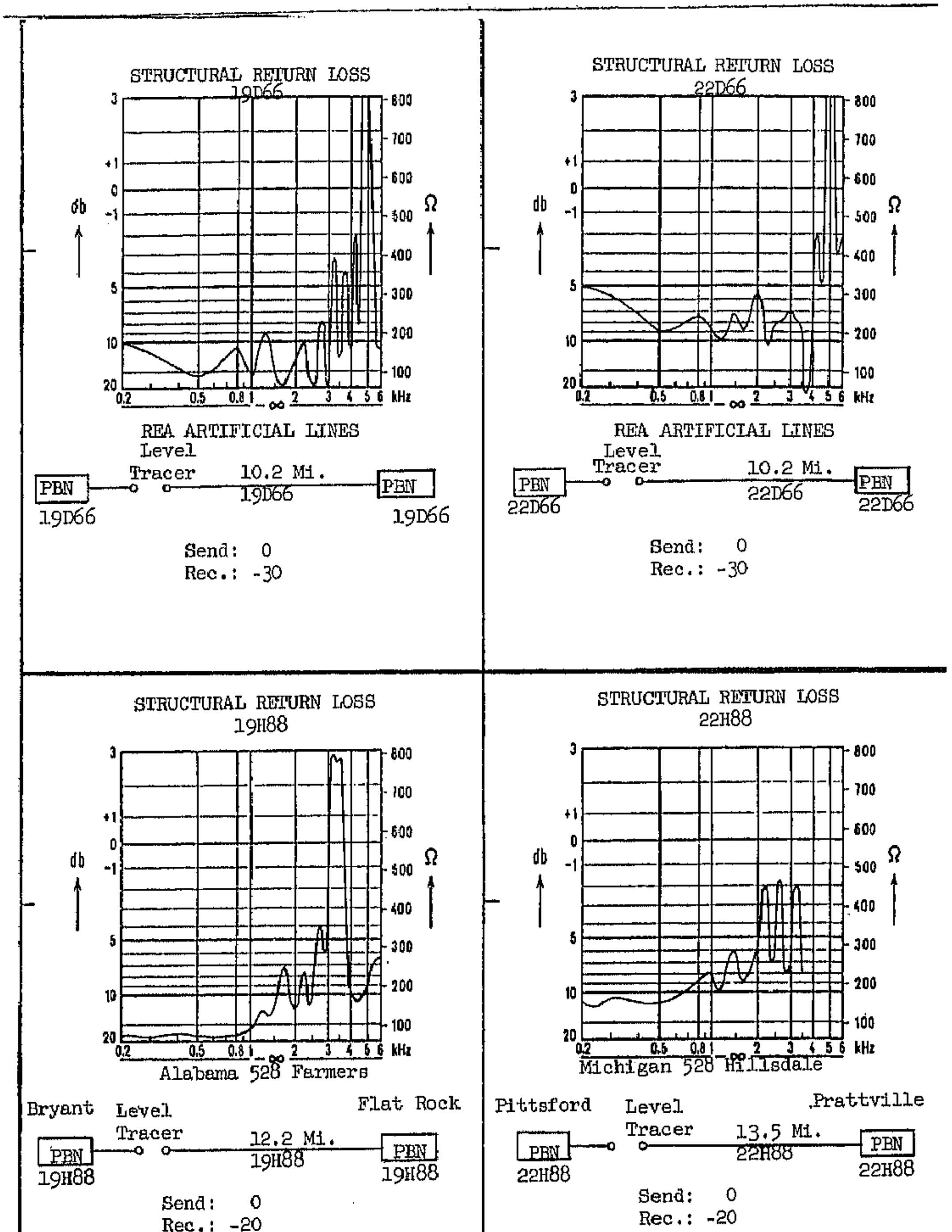


FIGURE 34

STRUCTURAL RETURN LOSS

EQPT. TYPE
(19) OSC H.P. 200 J
(20) AC-VTVM H.P. 400D
(21) HYB CEECO
(22) PBN NO.1 C-115 D
(23) PBN NO.2 115 H
PBN NO. 1
(24) CBO1 .025 MF
(25) GA 19
PBN NO. 2
(26) CBO2 .033 MF
(27) GA 22
OTHER
(28) C1 0 MF
(29) C2 0 MF
(30) OSC. CAL. LEV.[1] +7.7 DBM

[1] Cal. lev. of a 600-ohm osc. directly into a 600-ohm res.

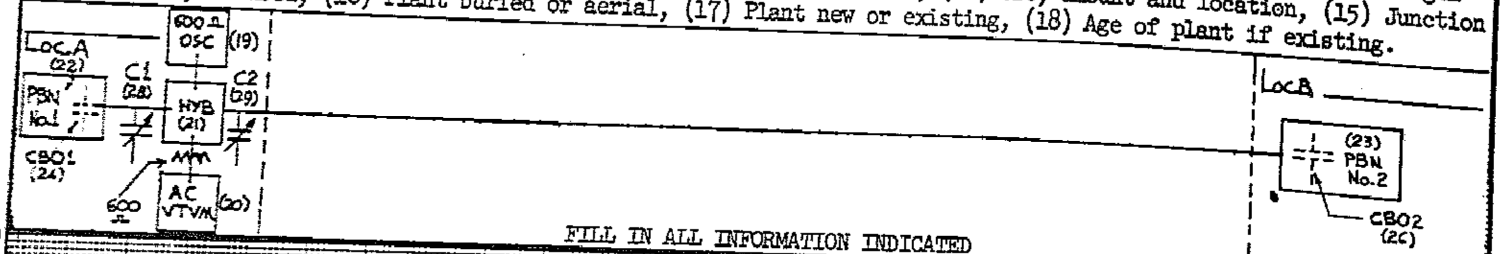


SFSRL USING THE SIEMENS-HALSKE CO. LEVEL TRACER

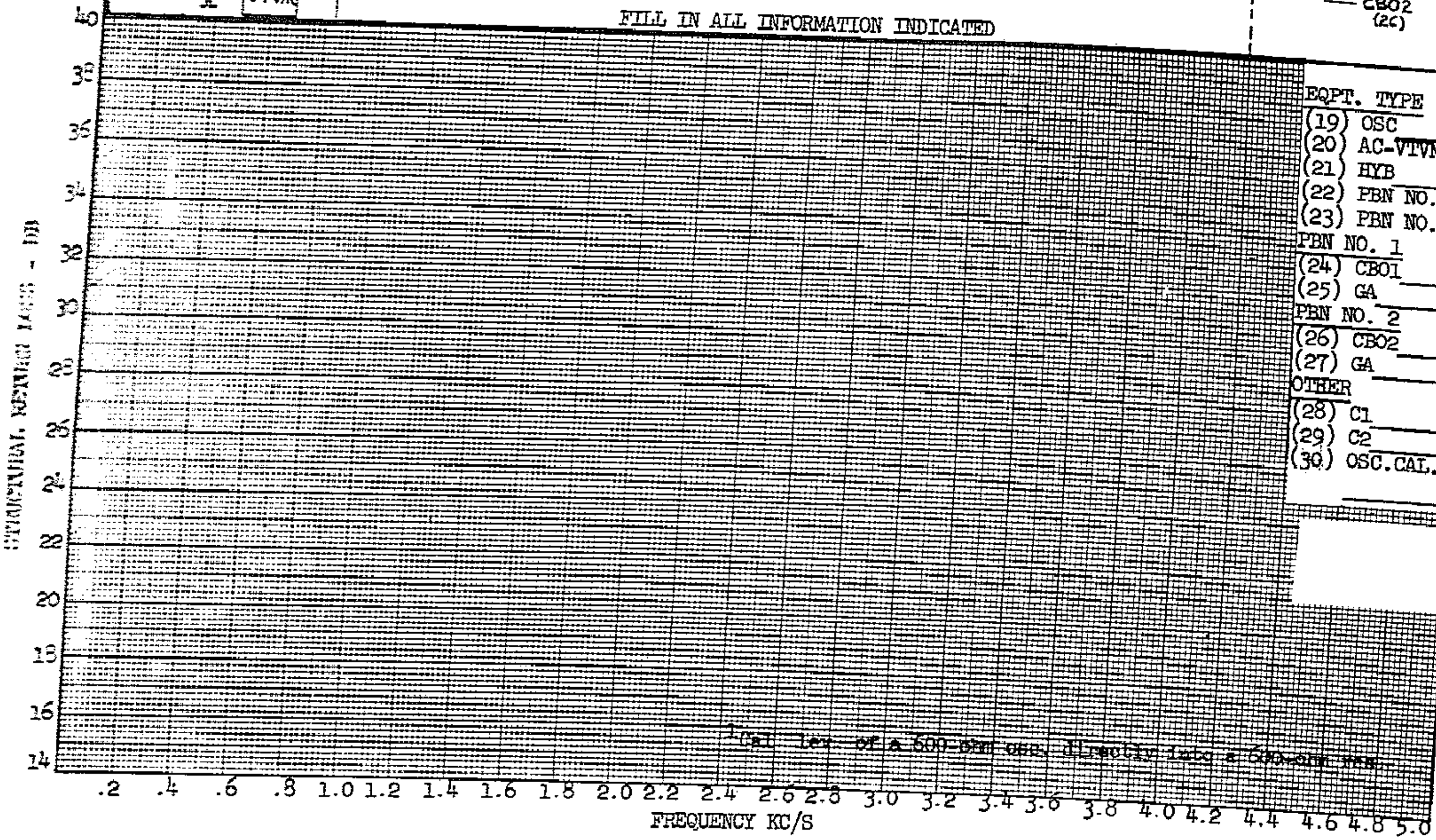
FIGURE 35

(4) MEASURING BETWEEN ______ TO ______ (2) ______ TO ______ (3) TOLL, EAS, SPEC. (Circle One)
(7) TEMP. AIR ____ °F (IF Aerial), GD.____ °F (If Buried) (5) TRUNK NO. LOC. A ___, LOC. B ___ (6) PAIR NO. LOC. A ___, LOC.B ___
(8) TESTERS ____________ (9) DATE MEASMS. ____________

In line diagram below show: (10) Type of loading system, (11) All gauges and length of each, (12) As-build length of each full-loading section, (13) As-built length of each end-section, (14) CBO, amount and location, (15) Junction Compensator, if used, (16) Plant buried or aerial, (17) Plant new or existing, (18) Age of plant if existing.



FILL IN ALL INFORMATION INDICATED



EQPT. TYPE
(19) OSC
(20) AC-VTVM ______
(21) HYB ______
(22) PBN NO.1 ______
(23) PBN NO.2 ______

PBN NO. 1
(24) CBO1 ______ MF
(25) GA ______

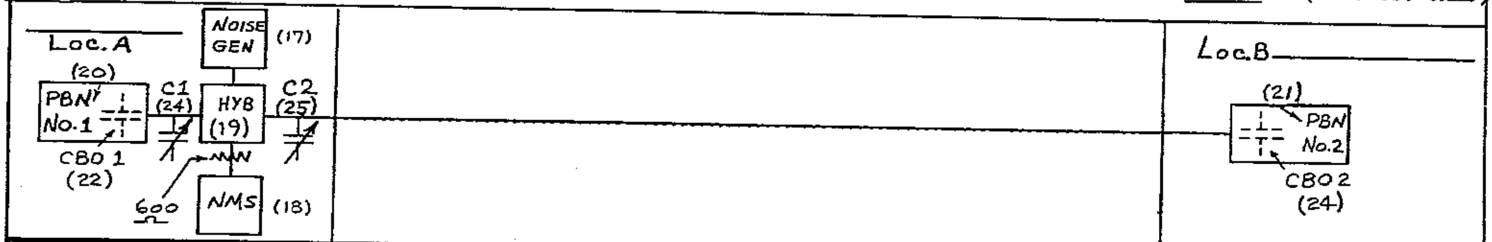
PBN NO. 2
(26) CBO2 ______ MF
(27) GA ______

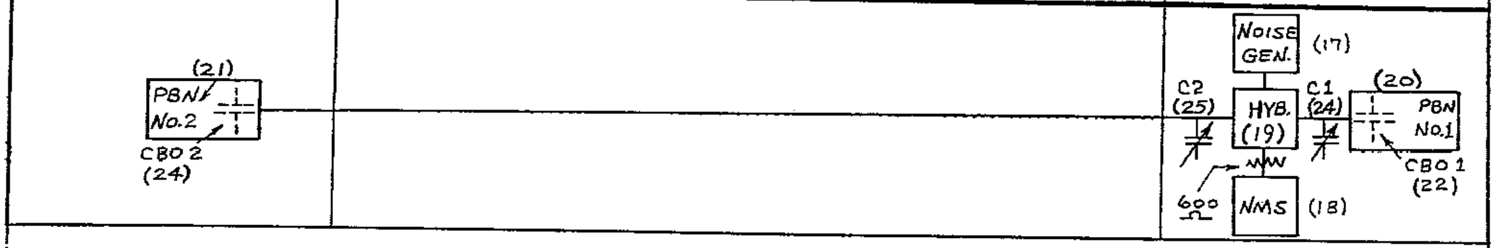
OTHER
(28) C1 ______ MF
(29) C2 ______ MF
(30) OSC.CAL.LEV.[1] ______ DBM

[1] Cal. lev. of a 600-ohm osc. directly into a 600-ohm res.

DATA SHEET - ECHO STRUCTURAL RETURN LOSS (ESRL) FOR H-88 LOADING

(1) REA PROJ. DESIGN.________________ (2) TRK.GROUP__________ TO__________ (3) TOLL, EAS, SPEC. (Circle One)
(4) MEASURING BETWEEN__________ TO__________ (5) TEMP. AIR______ °F (IF Aerial), GD.______ °F (If Buried)
(6) TESTERS__________ (7) DATE MEASMS.__________ In line diagram below show: (8) Type of loading system, (9) All gauges and length of each, (10) As-build length of each full-loading section, (11) As-built length of each end-section, (12) CBO, amount and location, (13) Junction Compensator, if used, (14) Plant buried or aerial, (15) Plant new or existing, (16) Age of plant if existing. EQUIPT. TYPE: (17) NOISE GEN.__________ (18) NMS__________
(19) HYB__________ (20) PBN NO. 1__________ (21) PBN NO. 2__________ PBN NO. 1: (22) CBO1______ MF (23) GA______ PBN NO. 2:
(24) CBO2______ MF (25) GA______ OTHER: (26) C1______ MF (27) C2______ MF (28) NOISE GEN. LEV.______ DBM (Into 600 ohms)





TRUNK NO.	PAIR NO. Loc. A	PAIR NO. Loc. B	MEASUREMENT AT LOCATION A ESRL (db)	MEASUREMENT AT LOCATION B ESRL (db)

★ U. S. GOVERNMENT PRINTING OFFICE : 1965 O - 750-460 (25)

(1) REA PROJ. DESIGN. IA. 501D (2) TRK.GROUP D... TO P... (3) TOLL, (EAS), SPEC. (Circle One)
(4) MEASURING BETWEEN DOWS TO POPETOY (5) TEMP. AIR 75 °F (IF Aerial), GD. ____ °F (If Buried)
(6) TESTERS ... (7) DATE MEASMS. 7/.../63 In line diagram below show: (8) Type of loading system, (9) All gauges and length of each, (10) As-build length of each full-loading section, (11) As-built length of each end-section, (12) CSO, amount and location, (13) Junction Compensator, if used, (14) Plant buried or aerial, (15) Plant (new) or existing, (16) Age of plant if existing. EQUIPT. TYPE: (17) NOISE GEN. W.E. 201E (18) NMS W.E. 3A (19) HYB FIG. 9 ALTE. (20) PBN NO. 1 FIG. 3 (21) PBN NO. 2 FIG. 3 PBN No.1: (22) GA 22 PBN No.2: (23) GA 22
OTHER: (24) C1 0 MF (25) C2 0 MF (26) C3 0 MF (27) NOISE GEN. LEVL +7 DBM (Directly into a 600 ohm resistor)

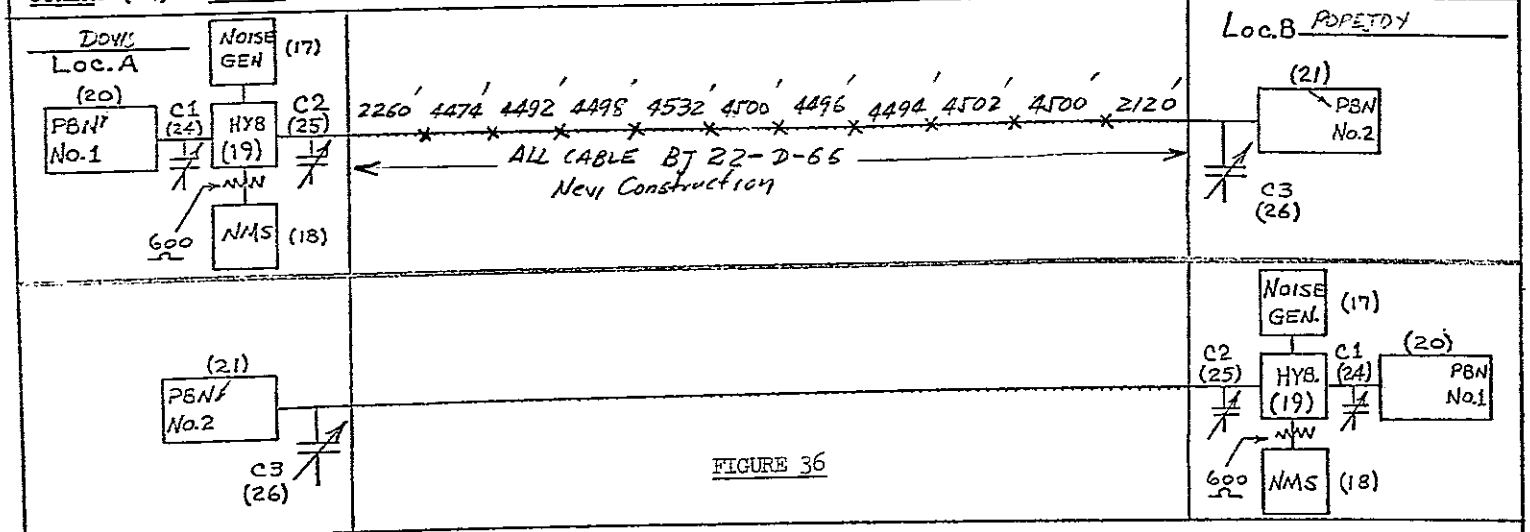
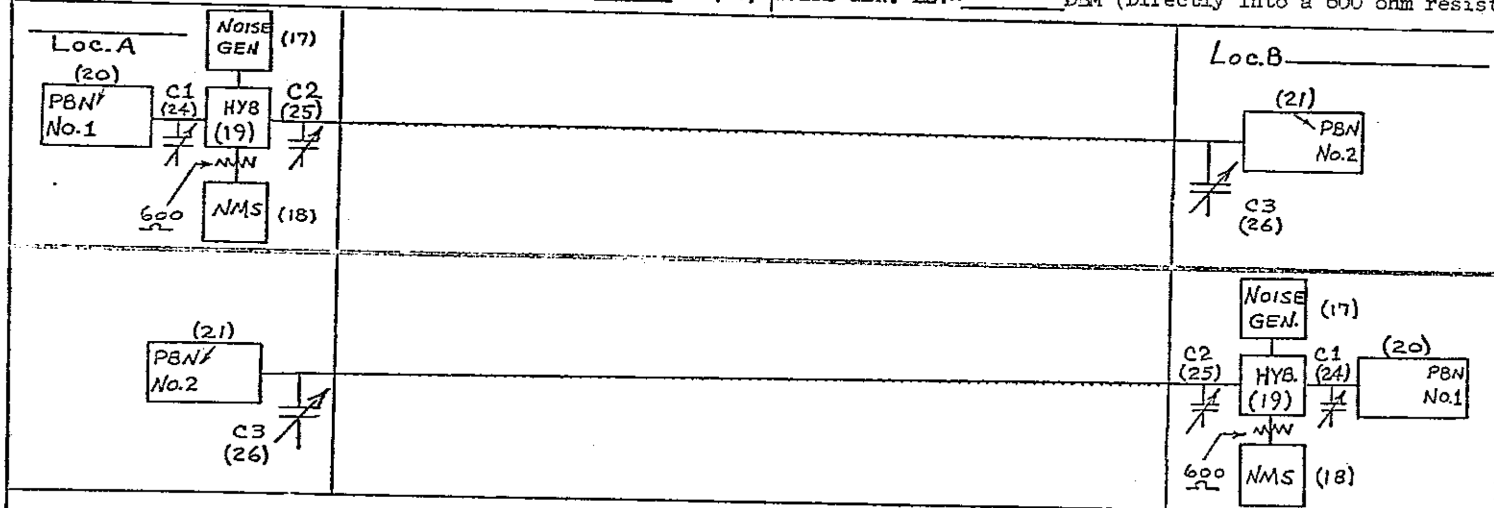


FIGURE 36

TRUNK NO.	PAIR NO. Loc. A	PAIR NO. Loc. B	MEASUREMENT AT LOCATION A ESRL (db)	MEASUREMENT AT LOCATION B ESRL (db)
1	1	1	89 - 52 = 37	NOT MEASURED
2	2	2	89 - 53.5 = 35.5	AT THIS TIME
3	3	3	89 - 50 = 39	
4			NOT MEASURED	
5	5	5	89 - 49.5 = 39.5	
6	6	6	89 - 48 = 41	
7	7	7	89 - 49 = 40	
8	8	8	89 - 50 = 39	

DATA SHEET - ECHO STRUCTURAL RETURN LOSS (ESRL) FOR D-66 LOADING

(1) REA PROJ. DESIGN.__________ (2) TRK.GROUP________ TO________ (3) TOLL, EAS, SPEC. (Circle One)
(4) MEASURING BETWEEN________ TO________ (5) TEMP. AIR_____ °F (IF Aerial), GD._____ °F (If Buried)
(6) TESTERS________ (7) DATE MEASMS.________ In line diagram below show: (8) Type of loading system, (9) All gauges and length of each, (10) As-build length of each full-loading section, (11) As-built length of each end-section, (12) CBO, amount and location, (13) Junction Compensator, if used, (14) Plant buried or aerial, (15) Plant new or existing, (16) Age of plant if existing. EQUIPT. TYPE: (17) NOISE GEN.________ (18) NMS________
(19) HYB________ (20) PBN NO. 1______ (21) PBN NO. 2______
OTHER: (24) C1_____ MF (25) C2_____ MF (26) C3_____ MF (27) PBN No.1: (22) GA_____. PBN No.2: (23) GA______
NOISE GEN. LEVL_______ DBM (Directly into a 600 ohm resistor



TRUNK NO.	PAIR NO.		MEASUREMENT AT LOCATION A	MEASUREMENT AT LOCATION B
	Loc. A	Loc. B	ESRL (db)	ESRL (db)